GROUNDWATER MONITORING PLAN

BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

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Prepared for:

Dominion
5000 Dominion Boulevard
Glen Allen, Virginia 23060

Prepared by:

COMMONWEALTH OF VIRGINIA
JAMES R. DIFRANCESCO
Lic. No. 025260
12-4-15
PROFESSIONAL ENGINEER

2108 W. Laburnum Ave., Suite 200
Richmond, Virginia 23227
Phone: 804 358-7900
Fax: 804 358-2900
www.golder.com

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1.0 INTRODUCTION

This *Groundwater Monitoring Plan* (GMP) was prepared for the Bremo Power Station (Facility) in Fluvanna County, Virginia, in accordance with the requirements of the Virginia Solid Waste Management Regulations (VSWMR) promulgated by the Virginia Waste Management Board, last amended in August 2011, and specific provisions of the Federal Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities; Final Rule (40 CFR 257; the CCR rule). This GMP has been prepared in general accordance with Department of Environmental Quality (DEQ) guidance (Submission Instruction No. 12, dated May 21, 2003), the VSWMR, and specific provisions of the CCR rule, and outlines the plan for collecting, analyzing, and managing groundwater samples and data from the uppermost aquifer underlying the two subject CCR surface impoundments (North and East Ash Ponds). These two impoundments are being closed by dewatering and stabilizing the CCR in place and installing an engineered final cover system, in accordance with the CCR rule. In the event that future amendments to the VSWMR conflict with any provisions of this GMP, the VSWMR will supersede this GMP, with the exception of DEQ-approved variances and Alternate Source Demonstrations (ASDs), and permit-specific conditions.

Dominion currently monitors groundwater quality for the North and East Ash Ponds pursuant to a Virginia Pollutant Discharge Elimination System (VPDES) permit (No. VA0004138). The VPDES groundwater monitoring program will continue throughout the impoundment closure construction project (annual sampling requirement). Once the closure is certified as complete, Dominion will establish the groundwater monitoring network and initiate the program addressed in this GMP within 90 days, and the VPDES monitoring program will be superseded by this VSWMR monitoring program.

Dominion intends to initiate the monitoring program under the monitoring, reporting, and record keeping requirements associated with the state program (VSWMR), modified to include constituents of potential concern identified in Appendices III and IV of the CCR rule as well as the current VPDES-required constituents.

If a Corrective Action Program is required at the Facility under the VSWMR, a *Corrective Action Monitoring Plan* will be developed at that time.

Monitoring of Facility groundwater to establish background concentrations of upgradient and downgradient wells will be consistent with the CCR rule. Background monitoring will commence within 90 days of certifying closure completion for the North and East Ash Ponds, and will conclude 24 months from commencement. Dominion will advise the DEQ of these activities once the background monitoring activities are initiated.

2.0 SITE LOCATION INFORMATION

The Bremo Power Station, owned and operated by Dominion Virginia Power, is located in Fluvanna County at 1038 Bremo Road, just east of Route 15 (James Madison Highway) and north of the James River. A site location map is presented as Drawing 1.

The Facility has recently converted from a coal-fired power plant to a natural gas-fired power plant. CCR from historical operations is stored in three inactive CCR surface impoundments on-site (North Ash Pond, West Ash Pond, and East Ash Pond). In addition, a storm water management pond is located north of the Former Coal Yard, and a Metals Pond is located near the western limits of the property. The Facility currently maintains a VPDES Permit (Permit No. VA0004138) that includes a groundwater monitoring program to address the CCR surface impoundments and water management ponds. Under the VPDES permit, the Facility is authorized to discharge water to the James River through permitted outfalls. A map of the Facility and ponds is provided as Drawing 2.

The North, West, and East Ash Ponds are being closed as inactive CCR surface impoundments under the federal CCR rule (40 CFR257). The West Ash Pond is currently completing closure by removal of CCR in accordance with 40 CFR §257.100(b)(5) of the CCR rule, which will be accomplished by April 17, 2018. The North and East Ash Ponds will achieve closure in accordance with 40 CFR §257.100(b)(1) through (4) of the CCR rule by leaving CCR in place, removing free liquids, and installing an engineered final cover system, which will also be completed by April 17, 2018. As closed, inactive CCR surface impoundments, the North, East, and West Ash Ponds are not subject to further requirements detailed in the CCR rule. During their operational lives, the ponds were regulated under the VPDES permitting program. However, their long-term management, which includes closure, post-closure care, and groundwater monitoring, will be governed by the VSWMR. The existing groundwater monitoring plan currently in effect under the VPDES permit will remain in effect until such time that it is superseded by a groundwater monitoring program pursuant to a solid waste permit for closure and post-closure in accordance with the VSWMR. Because they are being closed in place, the North and East Ash Ponds are the focus of this GMP. These two closed impoundments will be monitored under one multi-unit groundwater monitoring network.

The site consists of wooded, open, and developed land just north of the James River. The Facility's northern, eastern, and western boundaries are bordered by primarily undeveloped parcels, and the Facility is bordered to the south by a CSX rail line and the James River. Land use surrounding the Facility is classified as "A-1 Agricultural," and consists of undeveloped wooded and agricultural properties within a rural residential setting.

Slopes within the local area consist of undulating terrain deeply dissected by dendritic drainages. The Facility possesses two distinct gradients that slope southerly to southwesterly within its boundaries: 1) more level to slightly sloping grades in the southern sections of the Facility near the river, and 2) rolling land with moderately to steeply sloping grades and deep ravines in the northernmost and westernmost sections of the Facility.

Both intermittent and perennial streams characterize surface flow in the vicinity. Broad ridges and hilltops serve as topographical highs and extend to maximum elevations of roughly 450 feet above mean sea level (amsl) in the area. The James River receives stream discharges where grades of about 200 to 230 feet amsl exist within the floodplain.

2.1 Site History

The Facility is a former coal-fired power station that stored CCR in three impoundments (North Ash Pond, West Ash Pond, and East Ash Pond). The three CCR impoundments are located as shown on Drawing 2.

Historically, groundwater sampling and analysis have been performed at the Facility pursuant to the requirements of the VPDES permit and regulations governing underground storage tanks. Petroleum was formerly stored in the south-central section of the Facility near the coal storage area in accordance with 9VAC25-90-10 *et seq*. The VPDES permit did not require additional sampling for petroleum-related constituents, as those regulatory requirements were being met under 9VAC25-90-10 *et seq*. A review of historical petroleum releases for the Facility has identified the occurrence of two former releases. These release cases were subsequently closed under Pollution Control numbers 19800434 (February 2006) and 20156018 (November 2014).

Previously, the VPDES groundwater sampling program included sampling of two wells, one upgradient (Rec. Well) located north of the North Ash Pond and one downgradient (Ash Well) located south of the East Ash Pond. Groundwater from the wells was sampled at a frequency of once every 5 years and analyzed for barium, conductivity, iron, magnesium, pH, selenium, sulfate, and TDS. Currently (as of July 10, 2015), the VPDES groundwater monitoring program includes the sampling of 16 wells (2 hydraulically upgradient and 14 downgradient), as summarized in Table 1.

Monitoring wells MW-1 through MW-13 were installed in November and December 2012. Following installation and well development, quarterly VPDES background sampling for these wells and existing monitoring well MW-3 was completed between March 2013 and October 2014. A groundwater background report and statistical analysis of detected VPDES constituents and parameters were submitted to the DEQ on January 6, 2015, in a report titled: *Groundwater Background and Water Quality Report* (URS, 2015). Wells MW-14 and MW-15 were installed downgradient of the former coal pile in

January 2015, along with MW-16 in the East Ash Pond. Wells MW-14 and MW-15 were added to the VPDES monitoring network. Groundwater quality data for MW-14 and MW-15 were included and discussed in the Corrective Action Plan submitted to DEQ in April 2015.

As indicated in the VPDES groundwater background report, several constituents were detected at concentrations above background levels in samples from the downgradient wells: dissolved metals (arsenic, barium, iron, manganese, vanadium, and zinc), and water quality parameters (ammonia, chloride, hardness, sulfate, TDS, and pH). Dissolved arsenic was detected at levels above the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) in three wells downgradient from the East Ash Pond. These results are suspected of being biased high because the three wells (MW-7, MW-8, and MW-16) are likely screened in CCR. Detections above the Virginia Groundwater Quality Standards for ammonia and dissolved metals (arsenic, barium, cadmium, and zinc) were found in several wells during the 2-year monitoring period. A risk assessment submitted to DEQ on July 10, 2015, reported that constituents detected in groundwater (possibly related to CCR) along the southern, downgradient perimeter of the East Ash Pond do not pose risks in excess of regulatory levels to human health or the environment.

Additional monitoring wells MW-17 and MW-18 were installed in March 2015 as part of a hydrogeologic investigation. Boring logs for the constructed wells are provided in Appendix A of this report.

3.0 SITE GEOLOGY AND HYDROGEOLOGY

Topography within the local area consists of undulating terrain deeply dissected by dendritic drainages. Both intermittent and perennial streams characterize surface flow in the vicinity. Broad ridges and hilltops serve as topographical highs and extend to maximum elevations of roughly 450 feet amsl in the area. The James River receives stream discharges where grades of about 200 to 230 feet amsl exist within the floodplain. Local groundwater use is primarily for drinking water and agricultural purposes. Field reconnaissance completed in 2014 and an aerial map review indicate the closest residential land parcel is approximately 500 feet upgradient of the North Ash Pond. There are no known drinking water wells downgradient from the North or East Ash Ponds (between the ponds and the James River).

The regional and site hydrogeological characteristics were evaluated to determine the number, spacing, and depth of the proposed monitoring system. The following sections discuss the uppermost aquifer, including thickness, groundwater flow rate, groundwater flow direction, and seasonal and temporal fluctuations in groundwater flow. Also evaluated are the saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials comprising the uppermost aquifer, and materials comprising the confining unit defining the lower boundary of the uppermost aquifer, including, but not limited to: thicknesses, stratigraphy, lithology, hydraulic conductivities, porosities, and effective porosities.

3.1 Regional and Site Geology

The Facility is located in the central part of the Piedmont Physiographic Province. The surrounding area is characterized by undulating terrain incised by a number of dendritically patterned, intermittent and perennial stream channels flowing in a generally southern direction towards the James River. The Piedmont Physiographic Province is characterized by igneous and metamorphic rock formations of Pre-Cambrian (Catoctin Formation) to Devonian geologic age. The province consists of a mosaic of accreted terrain and has been folded and faulted near the end of Ordovician time. Regionally, the Facility is within the Central Virginia Volcanic - Plutonic Belt and southeast limb of the Blue Ridge anticlinorium.

As shown on Drawing 3 and according to the Virginia Division of Mineral Resources (VDMR) Geologic Map of the Dillwyn Quadrangle, the eastern half and portions of the western half of the Facility are underlain by likely Pre-Cambrian age medium- to coarse-grained gneissic quartz diorite, granodiorite, and granite of the Hatcher Complex (VDMR, 1969). The map indicates that the western portions of the Facility are also underlain by migmatitically interlayered hornblende gneiss of Pre-Cambrian age, and schist and slate units of Late Ordovician age of the Arvonia Formation. The Arvonia Formation rests unconformably with basal conglomerate upon gneissic granodiorite and quartz diorite of the Hatcher Complex.

The sequence of units was folded into asymmetrical and overturned anticlines and synclines (Arvonia Syncline near the western limits of Facility) near the end of Ordovician time. The units were later subjected to the last major period of regional metamorphism near the end of the Mississippian Period. Metamorphic grade generally increases from west to east across the county (VDMR, 1969)

Attitudes of the Arvonia Syncline bedding indicate a steep southeasterly dip along the west limb of the fold, and a vertical or nearly vertical dip along the east limb of the fold, indicating that the Arvonia syncline is asymmetrical with its axial plane, dipping steeply to the southeast. Bedrock foliation within the vicinity of the Facility is mapped as possessing a dominant northeasterly trend with varying attitudes of dip direction and angle. Northwesterly trending joints are also noted within bedrock underlying the Facility (VDMR, 1969).

As presented on Drawing 3, the portions of the Facility near the James River floodplain are immediately underlain by unconsolidated Quaternary-age alluvial sediments. The sediments were accumulated as a result of uplift and erosion of the igneous and metamorphic units.

3.2 Site Soil Units

Based on the information obtained during the Facility hydrogeologic and geotechnical investigations, the Facility soils are classified primarily as clays, silts, and sands (see Drawing 4). The Facility soils, with the exception of alluvial and colluvial materials, are predominantly derived from the deposition of weathered local parent rock material (residuum) and include predominantly more clay soils (slate parent rock) to the west and sandy soils (granite and granodiorite parent rocks) to the east of MW-6.

In general, approximately 20 feet of soil overburden is overlying bedrock at the Facility, with the exception of areas north of the East Ash Pond where bedrock is encountered at a depth of approximately 30 feet below grade. Previous hydrogeologic investigations in the vicinity of monitoring wells MW-7, MW-17, and MW-18 indicate a possible area of bedrock incision and relief to a depth of approximately 43 to 46 feet below grade. A cobble and/or sand/gravel layer has been identified just above the bedrock in several borings at the Facility, and bedrock elevations generally increase east of the East Ash Pond.

The United States Department of Agriculture (USDA) has mapped a variety of soils at the Facility (Drawing 4). The three major soil types within the immediate area of the Facility, based on area of coverage from greatest to least, are the Louisburg sandy loam, Appling sandy loam, and Congaree silt loam (USDA, 2015). The Louisberg and Appling sandy loam soils are associated with upland areas, and the Congaree silt loam is characterized as a lowland soil sometimes overflowed by the adjacent streams. None of the soils beneath the CCR impoundments exhibit hydric characteristics. In general, the sand and silt loam soils overlie a thin layer of sand and/or gravel/cobbles above bedrock at the Facility. Boring logs reviewed for monitoring wells MW-7, MW-8, MW-16, MW-17, and MW-18, located along the southern extent of the East Ash Pond, indicate that CCR material was encountered within the borings to a depth of approximately 20 feet below grade. Complete lithologic descriptions for the soils at the Facility are presented in the boring logs in Appendix A of this document.

3.3 Site Hydrogeology

The groundwater surface generally mimics site topography with groundwater movement from topographically high areas to topographically low areas. The uppermost aquifer beneath the Facility is unconfined and found in the surficially exposed overburden and bedrock. Locally, the groundwater flow direction in the uppermost aquifer is from the northeast to the southwest across the Facility towards the James River. Nested wells within the Facility boundary (MW-2 and MW-12) indicate a downward vertical hydraulic gradient at the Facility.

3.3.1 Description of the Uppermost Aquifer

Depth-to-water measurements have been obtained since 2012 from several observation and monitoring wells constructed at the Facility. The trend and range of fluctuation in the water table surface beneath the study area, with some exceptions, are relatively consistent across the study area, and presumably a function of long-term variations in precipitation and seasonal trends. As expected, the magnitude of the fluctuation is greater in those wells located in the upland areas and wells located at the western portions of the Facility where fine-grained slate bedrock is present, as opposed to those wells located near the East Ash Pond and those closer to the groundwater discharge boundary associated with the James River.

Depth to water in the unconfined aquifer beneath the Facility generally ranges from slightly more than 20 to 30 feet below grade along the southern portions of the Facility to more than 50 feet below grade in the elevated northern portions of the Facility. A Groundwater Contour Map for the unconfined aquifer is presented on Drawing 2. As presented, groundwater in the unconfined aquifer traverses the Facility in a north to south direction, convergent on the southeasterly flowing James River.

Analysis of slug testing data obtained from the observation wells in February 2012 indicates that the average hydraulic conductivity of the uppermost unconfined aquifer is 0.3 foot per day (ft/day). The hydraulic conductivity is based on analysis of the slug test data using Aqtesolv™ and the slug test evaluation methodology developed by Bouwer and Rice (1976). The slug test raw data, graphical analyses, and results are presented in Appendix B and Table 2. The effective porosity of the unconfined aquifer is estimated at 20% (Saunders, 1998).

3.3.2 Horizontal Component of Flow

Using the groundwater contours presented as an overlay on Drawing 2, the average hydraulic gradient for the unconfined aquifer in the vicinity of the North and East Ash Ponds was calculated as 7.6E-02 foot per foot (ft/ft) as shown below.

$$i_{gw} = \left({}^{h_L}/_{L}\right)$$

Where: h_L = head loss (elevation difference)
L = length (horizontal distance)

i = h_L/L = (320 - 210) / 1,452 = 7.6E-02 ft/ft

Using the estimated effective porosity value of 20%, the reported hydraulic conductivity value of 0.3 ft/day, and the calculated gradient, the average rate of groundwater flow (*Vgw*) in the unconfined aquifer was calculated using the algorithm below.

$$V_{gw} = K\, i\, \left({}^{1}/_{n_e}\right)$$

Where:

V_{gw} =	Groundwater velocity
K =	Hydraulic conductivity
i =	Hydraulic gradient
n_e =	Effective porosity

V_{gw} = [(0.3 ft/day) x (7.6E-02)] / 0.20
V_{gw} = 0.11 ft/day, or 41.6 ft/year

As presented above, the estimated horizontal rate of groundwater flow in the shallow unconfined aquifer beneath the study area is expected to average approximately 42 feet per year.

3.3.3 Vertical Component of Flow

Using the May 5, 2015, depth-to-water and elevation data, the vertical component of flow within the aquifer was evaluated using well pair MW-2/MW-12. The vertical gradients for these well pairs were calculated as shown below.

$$i_{gw} = \left({}^{h_L}/_{L}\right)$$

Where: h_L = head loss (elevation difference)
L = length (vertical distance – midpoint of the well screens)

$I_{MW-2/MW-12}$ = h_L/L = (213.00 feet AMSL – 204.12 feet AMSL) / 14.05 feet = 6.3E-01 ft/ft

The positive gradient for the MW-2/MW-12 well pair indicates that the hydraulic gradient is downward in this area of the Facility. Using the estimated effective porosity value of 20%, a vertical hydraulic conductivity value of 0.03 ft/day (estimated at 10% of the horizontal hydraulic conductivity), and the calculated gradients, the vertical rate of groundwater flow (*Vgw*) in the unconfined aquifer is expected to approximate 35 feet per year downward based on the following calculations.

$$V_{gw} = Kv\ i\ \left(1/n_e\right)$$

Where:
V_{gw} = Groundwater velocity
K_v = Hydraulic conductivity
i = Hydraulic gradient
n_e = Effective porosity

MW-2 and MW-12 Well Pair:

V_{gw} = [(0.03 foot/day) x (6.3E-01)] / 0.20
V_{gw} = 9.5E-02 foot/day, or 34.7 feet/year

4.0 DESIGN OF THE GROUNDWATER MONITORING SYSTEM

A multi-unit groundwater monitoring system is proposed to monitor the groundwater quality in the vicinity of the North and East Ash Ponds. The monitoring wells proposed for the compliance monitoring network are, or will be, located and constructed with a sufficient number of wells to yield groundwater samples representative of the conditions in the uppermost unconfined aquifer beneath the Facility that:

1. Accurately represent the quality of background groundwater, meets the requirement of 40 CFR §258.51(a), and will be as protective of human health and the environment as individual monitoring systems for each CCR management unit.

2. Accurately represent the quality of groundwater passing the boundary of the closed CCR impoundments. The downgradient monitoring system installed at the closed CCR impoundment boundary will ensure detection of groundwater contamination in the uppermost aquifer. When physical obstacles preclude installing downgradient monitoring wells at the closed CCR impoundment boundary, the downgradient monitoring wells may be installed at the closest practicable distance hydraulically downgradient from the boundary in locations that ensure detection of groundwater contamination in the uppermost aquifer, if any.

Well placement, construction, development, and decommissioning procedures are discussed in the following sections. Recommended monitoring well construction, development, and decommissioning procedures are presented in Appendix C.

4.1 Special Conditions

Based on the available hydrogeologic information for the Facility, Dominion is not aware of any special conditions that would affect the ability of Dominion to effectively monitor the uppermost aquifer beneath the Facility using a conventionally located and constructed multi-unit groundwater monitoring network.

4.2 Monitoring Well Network

The monitoring network described herein is designed to meet the performance standards specified in the VSWMR, and will be protective of human health and the environment. Accordingly, the monitoring network is designed so that adequate monitoring coverage is provided to represent the quality of groundwater upgradient and downgradient of the North and East Ash Ponds. Ten groundwater monitoring wells (MW-11, MW-15, and MW-19 through MW-26) are proposed as the compliance monitoring network for the North and East Ash Ponds.

Monitoring wells MW-19 through MW-26 are currently not constructed. Monitoring wells MW-11 and MW-15 are existing wells, with MW-11 part of the existing VPDES compliance monitoring network as its upgradient/background well. Monitoring wells MW-11 and MW-24 are proposed as the upgradient/background monitoring wells, and wells MW-15, MW-19 through MW-23, MW-25, and MW-26 are the proposed downgradient compliance wells for the new monitoring well network.

A summary of the well construction information for the existing monitoring and observation wells is provided in Table 1. Drawing 2 presents the proposed multi-unit groundwater monitoring network. It should be noted that the proposed locations for the new wells illustrated in Drawing 2 are approximate, pending pond closure design and construction. The exact locations of the monitoring wells will be determined and installation will occur after closure construction has been completed. It also may be necessary to decommission selected existing monitoring wells due to closure construction and relocate the wells following completion of closure activities. Wells MW-6, MW-7, MW-8, MW-10, MW-16, MW-17, and MW-18 are currently planned for decommissioning.

4.3 Monitoring Well Construction

Well construction logs for the existing wells to be used in the proposed compliance monitoring network (MW-11 and MW-15) are presented in Appendix A. Monitoring well MW-11 was constructed in 2012 and MW-15 in 2015. Monitoring wells MW-19 through MW-25 are to be constructed prior to the collection of background samples, as shown on Drawing 2. The locations of these monitoring wells were selected based on the CCR management unit boundaries, the defined limits of CCR, and the site topography and natural drainage areas directing groundwater flow towards the proposed monitoring well locations. The existing and future monitoring wells proposed for the monitoring network are, or will be, constructed with a minimum 10-foot length of screen (typical compliance well will be constructed with 10 feet of screen), and screened within the uppermost aquifer.

Wells are, or will be, completed with a locking protective standpipe and a concrete apron for surface protection. Construction of new monitoring wells will be performed in accordance with the specifications presented in Appendix C. Monitoring wells will be maintained such that they perform to design specifications throughout the life of the monitoring program. Dominion will document and record the design, installation, and development of any monitoring wells, piezometers, and other measurement, sampling, and analytical devices.

4.3.1 Drilling Methods

Drilling new monitoring wells and/or observation wells will be performed in accordance with the specifications presented in Appendix C. A qualified groundwater scientist will prepare a boring and well construction log for each new well. The owner/operator will transmit the boring logs, well construction logs, and appropriate maps for any wells to be included in the permitted network to the DEQ within 14 days of certification by the qualified groundwater scientist in accordance with the VSWMR. Available boring logs and well construction diagrams for existing observation and monitoring wells are provided in Appendix A.

4.3.2 Well Development

Existing wells were generally developed using a well development pump to remove particulates present in the well casing, filter pack, and adjacent aquifer matrix due to construction activities.

Newly constructed wells will be developed to remove particulates that are present in the well casing, filter pack, and adjacent aquifer matrix due to construction activities. Development of new monitoring wells will be performed at least 24 hours after well construction. Wells may be developed with disposable polyvinyl chloride (PVC) bailers, a well development pump, or other approved method. Well development procedures are presented in Appendix C.

Samples withdrawn from the Facility's monitoring wells should be clay- and silt-free; therefore, wells may require redevelopment from time to time based upon observed turbidity levels during sampling activities. If redevelopment of a monitoring well is required, it will be performed and documented in a manner similar to that used for a new well.

4.3.3 Documentation

Documentation of future well construction activities will be in accordance with the VSWMR. New wells will be surveyed by a licensed surveyor to within ±0.05 foot on the horizontal plane and ±0.01 foot vertically in reference to mean sea level. A boring log, well construction log, groundwater monitoring network map, and installation certification will be submitted to the DEQ within 14 days of certification by the qualified groundwater scientist in accordance with the VSWMR. The certification shall occur within 30 days of well construction.

4.4 Monitoring Well Decommissioning Procedures

If a monitoring well becomes unusable during the life of the monitoring program, the Facility operator will make reasonable attempts to decommission the monitoring well in accordance with the procedures presented in Appendix C.

4.4.1 Documentation

DEQ approval will be obtained prior to decommissioning any monitoring wells that are in the Facility's compliance monitoring network. A report describing the decommissioning procedures will be transmitted to DEQ following completion of the decommissioning activities.

4.5 Well Operations and Maintenance

In accordance with 9VAC20-81-250.A, the compliance monitoring wells will be operated and maintained so they perform to their design specifications throughout the life of the monitoring program.

5.0 GROUNDWATER MONITORING PROGRAM

Dominion will implement groundwater monitoring activities under the VSWMR for constituents and parameters listed in the CCR rule, the VSWMR (inorganic constituents only), and the current VPDES permit. This GMP is intended to provide a framework for consistent sampling and analysis procedures (as provided in Section 6.0) that is designed to ensure monitoring results from the groundwater monitoring program provide an accurate representation of groundwater quality at the upgradient/background and downgradient wells. Details for the VSWMR monitoring program modified for CCR constituents and parameters, including upgradient/background sampling requirements, are presented in the following sections.

5.1 VSWMR Modified Monitoring Program for CCR Units

This modified CCR Unit Monitoring Program is designed to identify the presence and concentration of targeted CCR constituents and parameters in the uppermost aquifer beneath the Facility. Components of the CCR Unit Monitoring Program, including analytical requirements, sampling frequency, and data evaluation are discussed in the following sections.

5.1.1 Constituents

The CCR Unit Monitoring Program will involve purging and sampling the compliance monitoring wells for analysis of the required constituents of potential concern. These constituents comprise the combined lists of constituents required by the CCR rule (Appendices III and IV), the inorganic constituents listed in VSWMR Table 3.1 Columns A and B, and the constituents required by the current VPDES permit's groundwater monitoring program. Required analytical methods and associated Practical Quantitation Limits (PQLs) for these parameters are presented in Appendix D of this report. The 35 constituents to be monitored under this GMP are as follows:

Alkalinity	Chromium	Manganese	Sulfate
Antimony	Cobalt	Mercury	Sulfide
Arsenic	Copper	Nickel	Total Dissolved Solids
Barium	Cyanide	Molybdenum	Total Organic Carbon
Beryllium	Iron	pH	Thallium
Boron	Fluoride	Radium 226/228	Tin

Cadmium	Hardness	Selenium	Vanadium
Calcium	Lead	Silver	Zinc
Chloride	Lithium	Sodium	

5.1.2 Background Sampling Period and Report

A minimum of eight independent samples shall be collected from each upgradient and downgradient compliance well during the background sampling period. Monitoring Facility groundwater to establish background concentrations of wells upgradient and downgradient of the North and East Ash Ponds will be consistent with the CCR rule. Background monitoring will commence within 90 days of certifying closure completion for the North and East Ash Ponds, and conclude 24 months from commencement. The background sampling events will be performed approximately quarterly to account for both seasonal and spatial variability in groundwater quality for the constituents listed in Section 5.1.1. Data will be collected from the two upgradient/background wells (MW-11 and MW-24) and the eight downgradient wells (MW-15, MW-19 through MW-23, MW-25, and MW-26).

5.1.3 Sampling Schedule

After establishing Facility background concentrations, the CCR Unit Monitoring Program sampling schedule will be based on a semi-annual schedule in accordance with the VSWMR (once every 180 days plus or minus 30 days).

5.1.4 Groundwater Protection Standards

Within 90 days of obtaining the results from the first post-background semi-annual event, Dominion will establish Groundwater Protection Standards (GPS) for the Facility. The GPS shall be as follows:

- For constituents for which a MCL has been promulgated under Section 1412 of the Safe Drinking Water Act (40 CFR Part 141), the MCL for that constituent;
- For constituents for which MCLs have not been promulgated, the background concentration, as approved by DEQ, and established from the upgradient wells; or
- For constituents for which the background level is higher than the MCL, the background concentration, as approved by the DEQ.

5.1.5 Evaluation and Response

After establishing Facility background concentrations, Dominion will perform the following evaluations in response to the detection of constituents in downgradient wells at quantified concentrations.

- If all detected constituents are shown to be at or below established Facility background concentrations but below the GPS using appropriate statistical procedures, sampling and analysis activities will continue under the CCR Unit Monitoring Program, with the sampling and analysis results reported with the statistical evaluation results in a semi-annual monitoring report to be submitted to the DEQ within 120 days of completing the laboratory analyses for the sampling event.

- If any detected constituents are shown to be present at concentrations above the established GPS using appropriate statistical procedures, Dominion will notify the DEQ in writing within 14 days of this finding. The notification will indicate whether Dominion intends to initiate a Corrective Action Program within 90 days, or prepare and submit an Alternate Source Demonstration to the DEQ for approval within 90 days, or longer as approved by DEQ.

5.1.6 Alternate Source Demonstration

In accordance with the VSWMR, the operator may demonstrate that a source other than the CCR unit(s) caused the detection of a constituent or parameter at a concentration above Facility background, or that a statistically significant detection resulted from an error in sampling procedures, analysis, statistical procedures, or natural variation in groundwater quality. The Alternate Source Determination (ASD) must be submitted to and approved by the DEQ within 90 days of confirming the statistical exceedance to avoid advancing into the Corrective Action Program, unless an extension for good cause is granted by the DEQ.

If the ASD is approved by the DEQ, the operator may continue with the CCR Unit Monitoring Program. If the ASD is not approved by the DEQ, the operator will initiate the Corrective Action Program by undertaking characterization and assessment activities.

6.0 SAMPLE AND ANALYSIS PROGRAM

Proper sampling procedures are an important and fundamental aspect in an effective monitoring program. The following sections outline the proposed sample collection procedures and are consistent with EPA guidance and the requirements of the CCR rule.

6.1 Sampling Order

The existing and proposed compliance wells are, or will be, equipped with dedicated purging and sampling equipment; therefore, the likelihood of cross-contamination at this Facility is minimized. Accordingly, the anticipated sampling order will follow a sequence based on consideration of field conditions at the time of sampling.

6.2 Water Level Gauging

Prior to purging each monitoring well, the static water level will be gauged using an electronic water level indicator accurate at 0.01 foot. The measurement will be obtained from the surveyed measuring point (typically a notch in the top of the PVC casing) on each well.

Prior to initial use and between wells, the portion of the water level indicator that comes in contact with the groundwater in the well will be decontaminated to avoid cross-contamination between monitoring wells. In addition to decontaminating the downhole equipment, sampling personnel will don new gloves between wells, and more frequently as needed, to avoid cross-contamination between monitoring wells.

The depth-to-water and depth-to-bottom measurements will be used to calculate the volume of water in the monitoring well using the following equation in the case that micropurge techniques are not used.

Well Volume (gallons) = (DTB – DTW) * V_F

Where:
DTB = Depth to bottom to the nearest 0.1 foot
DTW = Depth to the water table surface to the nearest 0.01 foot
V_F = Volume Factor as follows:
0.17 = 2-inch diameter well

6.3 Purging Procedure

The monitoring wells in the monitoring network will be sampled using a micropurge technique. Micropurge sampling can greatly reduce the volume of water that must be purged from a well before representative samples can be collected, and typically provides for the collection of more representative samples than do other purge methods, as well as consistency in analytical results between sampling events. Micropurging is accomplished through the use of dedicated low-flow sampling devices. Bailers and portable pumps are not recommended because they cause mixing of the standing water column within the well (Robin and Gilham, 1987). This mixing action requires the removal of the traditional large purge volumes before sampling. Introducing any device into the well prior to sampling causes a surging effect that may increase turbidity and interfere with the normal flow of water through the well screen. This disturbance may remain in effect for as long as 24 to 48 hours (Kearl *et al.*, 1992).

For monitoring wells with dedicated bladder pumps equipped with check values that hold stagnant water in the discharge tubing between sampling events, the discharge tubing shall be purged prior to commencing micropurge activities to ensure that fresh formation water is sampled following the completion of micropurging. The discharge tube purge volume will be determined using the following equation:

Discharge Tube Volume (milliliters) = $DTP * V_F$

Where: DTP = Depth to the top of the pump to the nearest 0.1 foot

V_F = Volume Factor as follows:

10 = 1/4-inch diameter tubing
22 = 3/8-inch diameter tubing
39 = 1/2-inch diameter tubing

If discharge tube purging is required, the purge should be conducted at a rate equal to the well yield to avoid drawing stagnant well column water into the pump (*i.e.*, between 100 and 500 milliliters per minute). During the discharge tubing purge, the flow rate and the depth to groundwater should be monitored on regular intervals (every 3 to 5 minutes) to verify that the purge activities are not removing stagnant water from the water column in the monitoring well.

After completing the discharge tubing purge, if required, water quality parameters (pH, temperature, conductivity) will be monitored during the micropurge consistent with EPA guidance on micropurging. The stabilization of these parameters (generally 10% for three consecutive readings) indicates when the discharge water is representative of formation water and samples can be collected for analysis. Measurements of turbidity may also be collected for the purpose of evaluating the purging technique. Water quality measurements will be collected on approximate 3- to 5-minute intervals and will be recorded on a Field Log or in the Field Book to document purge stabilization.

In addition to the water quality parameters, the flow rate may be monitored on regular intervals during the micropurge to verify that the micropurge activities are not removing stagnant water from the water column in the monitoring wells. In general, purge rates when using micropurge sampling procedures should not exceed 500 milliliters per minute. Any measurements taken should be recorded on a Field Log or in the Field Book to document steady-state flow conditions during the purge. Sampling personnel will containerize and dispose of purge water generated during sampling activities in the Facility's leachate collection system or by another approved means.

On rare occasions, the yield of a monitoring well will be insufficient to keep up with the micropurge. In cases where the yield of the monitoring well is less than 50 milliliters per minute as documented by the recorded flow rate and continually decreasing head level as the well is purged, the required samples may be collected prior to stabilization of the water column provided the water quality parameters have stabilized within the required 10% range.

In the event that dedicated pumping equipment malfunctions during a sampling event, non-dedicated equipment may be used to micropurge the affected well(s) provided the pump can be decontaminated prior to use in each well. The pump and associated discharge hoses must be decontaminated using a non-phosphate-based detergent and water mixture followed by a deionized water rinse to avoid cross-contamination between monitoring wells.

6.4 Sample Collection

Once the water quality data indicate that the well has been stabilized, required samples should be collected directly from the discharge tubing on the pump into laboratory-provided, pre-preserved sample containers selected for the required parameters or compatible parameters. Sample collection should be performed at the same rate that was used during the micropurge.

Anticipated sample container, minimum volume, chemical preservative, and holding times for each analysis type are provided in Table 3, and may change depending on laboratory requirements. Sample preservation methods will be used to retard biological action, retard hydrolysis, and reduce sorption effects. These methods include chemical addition, refrigeration, and protection from light.

6.5 Sample Documentation

Chain-of-custody control is critical for documenting the integrity of the samples following collection, during transport to the laboratory, and at the laboratory. Consequently, the label for each sample container shall be completed to document the sample collection activities.

After labeling the sample containers, the samples should be documented on the chain-of-custody form prior to mobilizing to the next sample point.

In addition, the chain-of-custody form should be signed by the sampling personnel and the receiving agent, with the date and time of transfer noted. The completed chain-of-custody form should be maintained with the samples.

6.6 Sample Seals

It is recommended that the shipping container be sealed to ensure that the samples have not been disturbed during transport to the laboratory.

6.7 Sample Event Documentation

The sampling event field notes should document the field activities such that they, along with the chain-of-custody form(s), are sufficient to allow for reconstructing the sampling event by a third party.

6.8 Field Quality Assurance/Quality Control Procedures

Trip blanks, equipment blanks, and field blanks provide quality assurance / quality control (QA/QC) measures for the monitoring program. The QA/QC measures are discussed in the following sections.

6.8.1 Trip Blanks

Trip blanks will not be required as none of the CCR rule Appendices III or IV analytical parameters are volatile organic compounds (VOCs). Trip blanks are a required part of the field sampling QA/QC program whenever analytical parameters include VOCs.

6.8.2 Field Blanks

Field blanks may be collected as part of the field sampling QA/QC program. The purpose of the field blank is to detect any contamination that might be introduced into the groundwater samples through the air or through sampling activities. For this groundwater sampling program, at least one field blank is recommended to be collected and analyzed for the same parameters as those for which groundwater samples are analyzed.

Field blanks must be prepared in the field (at the sampling site) using laboratory-supplied bottles and deionized or laboratory reagent-quality water. Each field blank is prepared by pouring the deionized water into the sample bottles at the location of one of the wells in the sampling program. Preservatives are added to specific sample bottles as required. The well at which the field blank is prepared must be identified on the Field Log along with any observations that may help explain anomalous results (*e.g.*, prevailing wind direction, upwind potential sources of contamination). Once a field blank is collected, it is handled and shipped in the same manner as the rest of the samples.

Field blank results will be reported in the laboratory results as separate samples, using the designation FB-(Well #) as their sample point designation.

6.8.3 Equipment Blanks

Equipment will be decontaminated by rinsing the equipment once with deionized or laboratory reagent-quality water, brushing the equipment using laboratory-quality soap, and triple rinsing the equipment with deionized or laboratory reagent-quality water. One equipment blank may be collected during each sampling event and analyzed for the same parameters as those for which groundwater samples are analyzed. Equipment blanks are collected by pouring deionized or laboratory reagent-quality water into or over the sampling device (*e.g.*, the water level indicator), and then filling a set of sample bottles.

If the analytes for the equipment blank would normally be filtered, this water should be placed into a pre-filtration bottle and subsequently filtered. Whether or not it is filtered, this water is placed into the equipment blank bottles, and the proper preservative added (as required).

Equipment blank results will be reported in the laboratory results as separate samples, using the designation EB-(Well #) as their sample point designation.

6.9 Laboratory Quality Control Procedures

The quality assurance program for the Virginia Environmental Laboratory Accreditation Program (VELAP)-accredited analytical laboratory will be documented in their Quality Assurance Program Plan (QAPP). This document describes mechanisms employed by the VELAP-accredited laboratory to ensure that reported data meet or exceed applicable EPA and state requirements. It describes the laboratory's experience, its organizational structure, and procedures in place to ensure quality of the analytical data. The QAPP outlines the sampling, analysis, and reporting procedures used by the laboratory. The laboratory is responsible for the implementation of and adherence to the QA/QC requirements outlined in the QAPP. A copy of the laboratory's QAPP will be available to the DEQ or Facility personnel upon request.

Data Quality Reviews (DQRs), or equivalent, are requests submitted to the laboratory to formally review results that differ from historical results, or that exceed certain permit requirements or quality control criteria. The laboratory prepares a formal written response to DQRs explaining discrepancies. The DQR is the first line of investigation following any anomalous result.

6.9.1 Laboratory Documentation

Upon receipt of the samples at the laboratory, the following activities are recommended:

- The date, time of sample collection, and analysis to be performed will be provided to the VELAP-accredited laboratory.
- The samples will be examined upon receipt to ensure collection in EPA-approved containers for the requested analysis. The sample collection data and time will also be reviewed to ensure the EPA-required sample holding time has not expired or will not expire before the analysis can be performed.
- Samples will be shipped in accordance with 40 CFR 136.
- The pH of each sample will be recorded if required by the analytical method. Also, preservative adjustments, filtration, and sample splitting must also occur as required prior to distribution. Sample adjustments will be fully documented.

During analysis of the samples, it is recommended that the laboratory agent maintain the integrity of the samples as follows:

- During the sample analysis period, the samples will be stored in accordance with 40 CFR 136.
- If, at any point during the analysis process, the results are considered technically inaccurate, the analysis must be performed again if holding times have not been exceeded.

Documentation activities should be completed with permanent ink in a legible manner with mistakes crossed out.

6.9.2 Laboratory Analyses

Analytical procedures will be performed in accordance with EPA's *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846,* as updated, and other EPA-approved methods. The Detection Monitoring Program and Assessment Monitoring Program constituents are listed in Appendix D of this GMP along with proposed test methods and PQLs. The proposed methods are EPA-approved SW-846 methods.

Alternate methods may be used if they have the same or lower PQL. Methods with higher PQLs will be considered if the concentration of the parameter is such that an alternate test method with a higher PQL will provide the same result.

6.9.3 Limits of Quantitation (LOQs)

Laboratory-specific LOQs will be used as the reporting limits for quantified detections of required monitoring constituents. Laboratory LOQs should be reported with the sample results.

6.9.4 Limits of Detection (LODs)

Laboratory-specific LODs will be used as the reporting limits for estimated detections of required monitoring constituents. Constituents detected at concentrations above the LOD but below the LOQ will be reported as estimated with a qualifying "J" flag on the laboratory certificates of analysis. Laboratory LODs should be reported with the sample results.

6.9.5 Method Blanks

Laboratory method blanks are used during the analytical process to detect any laboratory-introduced contamination that may occur during analysis. A minimum of one method blank should be analyzed by the laboratory per sample batch.

6.9.6 Matrix Spike and Matrix Spike Duplicate Samples

A matrix spike/matrix spike duplicate sample will be run with every sample batch. The relative percent difference between the spike and the spike duplicate sample should be less than 20%. Higher values may indicate matrix interference.

7.0 DATA EVALUATION

Statistical analysis of the data will be completed as discussed in the following subsections. These criteria represent a conservative approach to groundwater analysis and incorporate appropriate statistical and other evaluation methodologies.

7.1 Groundwater Data Evaluation

This section outlines the inter-well statistical evaluation methodologies that may be used to detect a release from the Facility by comparing downgradient well results to background.

During background sample collection, it will be necessary to examine the data for outliers, anomalies, and trends that might be an indication of a sampling or analytical error. Outliers and anomalies are inconsistently large or small values that can occur due to sampling, laboratory, transportation, or transcription errors, or even by chance alone. Significant trends indicate a source of systematic error, or an actual contamination occurrence, that must be evaluated and corrected before valid inter-well statistical evaluations can be implemented. The inclusion of such values in the historical database used for temporal water quality evaluations or in the Facility's upgradient database for inter-well statistical evaluations could cause misinterpretation of the data set, and result in high false positive (i.e., an indication of a release when none exists) and/or false negative (*i.e.*, falsely concluding there is no release in the presence of an actual release) conclusions.

To prevent the inclusion of anomalous data in the inter-well database, background monitoring results will be evaluated during background development for any new wells constructed, once those well(s) have at least four measurements for a given constituent using time vs. concentration graphs. Parameter concentrations that appear anomalous (*i.e.*, that are 5 times or greater than the previous results) may be verified during the next sample collection event or after a reasonable period of time to ensure sample independence (*e.g.*, 3 months). If the anomalous result is not verified, the outlier will be removed from the database to maintain the accuracy of the evaluation method. Any detected systematic trends or verified outliers in the background database will be evaluated and reported to the DEQ in a timely manner.

7.1.1 Correcting for Linear Trends

If a data series exhibits a linear trend, the sample will exhibit temporal dependence when tested via the sample autocorrelation function (see Section 14.2.3 of the Unified Guidance; EPA, 2009), the rank von Neumann ratio (see Section 14.2.4 of the Unified Guidance; EPA, 2009), or similar procedure. These data can be de-trended by computing a linear regression on the data (see Section 17.3.1 of the Unified Guidance; EPA, 2009) and then using the regression *residuals* instead of the original measurements in subsequent statistical analysis.

7.2 Statistical Methodology

The statistical test used to evaluate the groundwater monitoring data will be the prediction interval method as allowed by the VSWMR and the CCR rule, unless this test is inappropriate with the background data. If one or more alternative statistical tests are used, the Facility operator will ensure that an adequate number of independent samples for the statistical method are collected within the compliance period such that the level of significance for individual well comparisons will be no less than 0.01 and no less than 0.05 for multiple comparisons for any statistical test. Possible alternate statistical test methods are:

1. A parametric analysis of variance (ANOVA) followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method will include estimating and testing the contrasts between each compliance well's mean and the background mean levels for each constituent;
2. An ANOVA based on ranks followed by multiple comparisons procedures to identify significant evidence of contamination. The method will include estimating and testing the contrasts between each compliance well's median and the background median levels for each constituent;
3. A tolerance or prediction interval procedure in which an interval for each constituent is established from the distribution of the background data, and the level of each constituent in each compliance well is compared to the upper tolerance or prediction limit;
4. A control chart approach that gives control limits for each constituent; or
5. Another statistical test method that meets the performance standards specified by the DEQ and CCR rule. A justification for the alternate test method will be submitted for approval by the DEQ.

The statistical analysis chosen to evaluate the groundwater data will meet the following performance standards and will be consistent with the DEQ's *Data Analysis for Solid Waste Facilities* (March 2008):

1. The statistical method used to evaluate groundwater monitoring data shall be appropriate for the distribution of monitoring parameters or constituents. If the distribution is shown by the owner or operator to be inappropriate for a normal theory test, then the data should be transformed or a distribution-free theory test should be used. If the distributions for the constituents differ, more than one statistical method may be needed.
2. If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a GPS, the test shall be done at a Type I error level no less than 0.01 for each testing period. If a multiple comparisons procedure is used, the Type I experiment-wise error rate for each testing period shall be no less than 0.05; however, the Type I error of no less than 0.01 for individual well comparisons must be maintained. This performance standard does not apply to tolerance intervals, prediction intervals, or control charts.
3. If a control chart approach is used to evaluate groundwater monitoring data, the specific type of control chart and its associated parameter values shall be protective of human health and the environment. The parameters shall be determined after considering the number of samples in the background database, the data distribution, and the range of the concentration for each constituent of concern.
4. If a tolerance interval or a prediction interval is used to evaluate groundwater monitoring data, the levels of confidence and, for tolerance intervals, the percentage of the population that the interval must contain, shall be protective of human health and the environment. These parameters shall

be determined after considering the number of samples in the background database, the data distribution, and the range of the concentrations for each constituent of concern.

5. The statistical method shall account for data below the LOD with one or more statistical procedures that shall be at least as effective as any other approach in this section for evaluating groundwater data. Any PQL that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions that are available to the Facility.
6. If necessary, the statistical method shall include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data.

7.2.1 Reporting of Low and Zero Values

Chemical constituents that are not present above the detection limit of the analytical procedure are reported as NOT DETECTED (ND), or less than the laboratory limit of detection (LOD), rather than as zero or not present, and the laboratory's LOD is provided on the analytical report. There is a variety of ways to deal with data that include values below detection. General guidelines that will be used to handle the data when less than 100% of the data are detected are summarized in Table 4.

However, procedures referenced above may be modified as discussed in Chapter 2 of *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance*, March 2009, and as agreed on with the DEQ on a case-by-case basis.

7.2.2 Normality Testing

The original data must be tested for normality using the Shapiro-Wilk Test of Normality (either single group or multiple group version) for sample size up to 50, and the Shapiro-Francia Test of Normality for sample size more than 50, or other acceptable test methods. If an alternative test method is proposed for evaluating the normality of data, the Facility operator will provide adequate supporting information demonstrating that the alternative method has a similar level of power to detect deviations from the normal distribution as the Shapiro-Wilk and Shapiro-Francia Test methods, as appropriate. The following guidelines are used for decisions in normality testing:

1. If the original data show that the data are not normally distributed, then the data must be natural log-transformed and tested for normality using the above methods.
2. If the original or the natural log-transformed data confirm that the data are normally distributed, then a normal distribution test must be applied.
3. If neither the original nor the natural log-transformed data fit a normal distribution, then a distribution-free test must be applied.

7.2.3 Missing Data Values

Missing data values may result in an incomplete measure of environmental variability and an increased likelihood of falsely detecting contamination. If data are missing, there is also a danger that the full extent of contamination may not be characterized. Therefore, resampling will occur within 30 days to replace the missing data unless an alternative schedule is otherwise approved by DEQ.

7.2.4 Outliers

An outlier is a value that is much different from most other values in a data set for a given groundwater chemical constituent. The reasons for outliers may include:

- Sampling errors or field contamination;
- Analytical errors or laboratory contamination;
- Recording or transcription errors;
- Faulty sample preparation or preservation, or shelf-life exceedance; or
- Extreme, but accurately detected environmental conditions (*e.g.*, spills, migration from the Facility).

Formal testing for outliers should be done only if an observation seems particularly high (by orders of magnitude) compared to the rest of the data set. If a sample value is suspect, one should run the outlier test described below, from EPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance*. It should be cautioned, however, that this outlier test assumes that the rest of the data values, except for the suspect observation, are normally distributed. Since log-normally distributed measurements often contain one or more values that appear high relative to the rest, it is recommended that the outlier test be run on the logarithms of the data instead of the original observations. That way, one can avoid classifying a high log-normal measurement as an outlier just because the test assumptions were violated.

The procedure for evaluating data for the presence of outliers is as follows. Let the sample of data be denoted by $X_1....X_n$. For specificity, assume that the data have been ordered and that the largest observation, denoted by X_n, is suspected of being an outlier. Generally, inspection of the data suggests values that do not appear to belong to the data set. For example, if the largest observation is an order of magnitude larger than the other observations, it would be suspect.

Step 1. Calculate the mean, *0*, and the standard deviation, S, of the data including all observations.

Step 2. Form the statistic, T_n:

$$T_n = (X_n - 0) / S$$

Note that T_n is the difference between the largest observation and the sample mean, divided by the sample standard deviation.

Step 3. Compare the statistic T_n to the critical value given the sample size, n, in Table 8, Appendix B of EPA's statistical analysis document referenced above. If the T_n

statistic exceeds the critical value from the table, this is evidence that the suspect observation, X_n, is a statistical outlier.

If the test designates an observation as a statistical outlier, the source of the abnormal measurement should be investigated. Valid reasons for the outlier value may include contaminated sampling equipment, laboratory contamination of the sample, errors in transcription of the data values, or the value may be a true, but extreme data point. Once a specific reason for the outlier is documented, the data point should be excluded from any further statistical analysis. If a plausible reason cannot be found, the sample should be treated as a true but extreme value and should be excluded from the current data evaluation round (*i.e.*, should not be used to calculate background concentrations). The value should be maintained in the Facility's database, however, with the database re-evaluated during the next data evaluation round.

7.3 Verification Procedure

Once groundwater analysis results have been collected, checked for QA/QC consistency, and determined to be above the appropriate statistical level, the results must be verified in accordance with the objectives of the VSWMR for groundwater monitoring. Verification re-sampling is an integral part of the statistical methodology described by EPA's *Addendum to Interim Final Guidance Document - Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* (July, 1992). Without verification re-sampling, much larger statistical limits would be required to achieve site-wide false positive rates of 5% or less. Furthermore, the resulting false negative rate would be greatly increased. The following procedure will generally be performed for each compound determined to be initially above its statistical limit. Only constituents that initially exceed their statistical limit will be analyzed for verification purposes.

7.3.1 Comparison to Groundwater Protection Standards

Following the establishment of GPS, detected constituents and parameters will be statistically compared to the approved GPS using one of the methods discussed below.

If the GPS for a constituent or parameter is derived from the Facility background concentration, then the groundwater monitoring data must be compared directly to the GPS using a value-to-value comparison. If the established GPS is derived from a MCL, then the groundwater monitoring data may be compared to the GPS statistically and/or using a value-to-value procedure.

Based on the above criteria, groundwater monitoring data will initially be compared to established GPS via a value-to-value comparison. If a GPS is exceeded during the value-to-value comparison for any parameter, a verification sample may be collected. The results from the verification sample will be compared to the GPS via a value-to-value comparison. If the comparison indicates a GPS exceedance, the source of the GPS will be determined. If the GPS is derived from a MCL, two additional groundwater samples for the suspect constituent(s) may be collected to facilitate a statistical comparison to the GPS. It is noted that verification sampling and/or additional sampling required to perform a statistical evaluation must occur within the same compliance monitoring period that the original samples were collected. The compliance monitoring period begins on the day of sampling and expires six months later, or the date of the next compliance sampling event, whichever occurs first.

To perform a statistical comparison, a minimum of four samples must be collected within the compliance monitoring period. Once data have been received for the four samples, then the lower confidence interval can be calculated and compared to the GPS. The lower limit should be calculated initially by using a 95% confidence level. If the lower limit exceeds the GPS, the DEQ may be contacted regarding the use of a confidence level greater than 95%.

8.0 HYDROGEOLOGIC ASSESSMENT

After each sampling event, groundwater surface elevations will be evaluated to determine whether the requirements for locating the monitoring wells continue to be satisfied and the rate and direction of groundwater flow will be determined. Groundwater elevations in monitoring wells must be measured within a period of time short enough to avoid temporal variations in groundwater flow (typically within 24 hours), which could preclude accurate determination of groundwater flow rate and direction.

The rate and direction of groundwater flow will be determined each time groundwater is sampled by comparing the groundwater surface elevations among the monitoring wells, and at least annually, preparing a groundwater surface contour map. The groundwater flow rate shall be determined using the following equation:

$$V_{gw} = K\,i\,\left({}^{1}/{}_{n_e}\right)$$

Where:	V_{gw} =	Groundwater velocity
	K =	Hydraulic conductivity
	i =	Hydraulic gradient
	n_e =	Effective porosity

If the evaluation shows that the groundwater monitoring system does not satisfy the requirements of the VSWMR, the monitoring system will be modified to comply with those regulations after obtaining approval from the DEQ. The operator will request the appropriate permit amendment action related to any revisions of the monitoring well network deemed necessary due to a change in groundwater flow pattern or functionality of any monitoring well. Proposed revisions will be submitted to the DEQ within 30 days of determining that the system does not satisfy the requirements of the VSWMR; the modifications may include a change in the number, location, or depth of the monitoring wells.

9.0 REPORTING

The results of each groundwater compliance monitoring event will be submitted to the DEQ semi-annually, including a description of field activities, a summary of the results, field logs, and the laboratory data package. The second semi-annual report each year may be included as part of the Annual Monitoring Report. The semi-annual and annual monitoring reports will be prepared and submitted to the DEQ within 120 days of completion of sampling and analysis pursuant to the VSWMR. The minimum requirements for the annual and semi-annual monitoring reports are presented in the VSWMR (9VAC20-81-250.E.2.a and E.2.b, respectively), as updated.

10.0 REFERENCES

DEQ. 2003. Submission Instructions No. 12. *Groundwater Monitoring and Sampling & Analysis for Existing Regulated Sanitary Landfills.* May 21.

DEQ. 2008. *Draft Data Analysis Guidelines for Solid Waste Facilities*. Office of Waste Programs. March.

EPA. 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. Office of Solid Waste and Emergency Response (OSWER). OSWER-9950.1. September.

EPA. 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance. Office of Resource Conservation and Recovery – Program Implementation and Information Division. March.

EPA. 2015. Federal Register. Volume 80. No. 74. Friday April 17, 2015. Part II. Environmental Protection Agency. *40 CFR Parts 257and 261. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule.* [EPA-HQ-RCRA–2009–0640; FRL–9919–44–OSWER]. RIN–2050–AE81. April.

Kearl, P.M., Korte, N.E., and Cronk, T.A. 1992. Suggested modifications to groundwater sampling procedures based on observations from the colloidal borescope: *Groundwater Monitoring Review*, v.12, No. 2, pp. 155-161.

Robin, M.L. and Gillham, R.W. 1987. Field evaluation of well purging procedures: *Groundwater Monitoring Review*, v.7, No. 4, pp.85-93.

Sanders, Laura L. 1998. *A Manual of Field Hydrogeology*, 1st Ed., Prentice Hall, 1998. p. 196.

URS. 2015. Groundwater Background and Water Quality Report, Bremo Power Station, Bremo Bluff, Virginia, VPDES Permit VA0004138. January 6.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2015. Soil Survey Geographic (SSURGO) Database for Fluvanna County, Virginia. USDA, Fort Worth, Texas Online Linkage: URL:http://SoilDataMart.nrcs.usda.gov/

Virginia Division of Mineral Resources (VDMR). 1969. Geology of the Dillwyn Quadrangle Virginia. Report of Investigations 10. Commonwealth of Virginia Department of Conservation and Economic Development Division of Mineral Resources. By William Randall Brown. Charlottesville, Virginia. 1969.

Virginia Division of Mineral Resources (VDMR). 1993. *Geologic Map of Virginia*. Virginia Division of Mineral Resources, scale 1:500,000.

Virginia Waste Management Board. 2011. Virginia Solid Waste Management Regulations – Amendment 8 (9VAC20-81 et seq.). August.

TABLES

Table 1
Summary of Construction Information for Investigative Borings and Observation Wells at the Facility
Bremo Power Station
Bremo Bluff, Virginia

Well Number	Northing	Easting	Top of Casing Elevation (feet AMSL)	Ground Surface Elevation (feet AMSL)	Well Construction	Well Depth (feet below top of casing)	Boring Depth (feet below ground surface)	Well Depth (feet below ground surface)	Sand Pack Interval (feet below ground surface)	Management Unit	Well Hydraulic Position	Date Constructed	Decommission/ Abandon	Monitoring Program
MW-1	3783032.883	11542749.05	221.76	218.95	2" PVC with 10-foot screen interval	24.4	21.5	21	9 - 21	West Ash Pond	Upgradient	12/4/2012	No	VPDES
MW-2	3782311.645	11542592.43	218.98	216.57	2" PVC with 10-foot screen interval	22.41	21	20	8 - 20	West Ash Pond	Downgradient	11/30/2012	No	VPDES
MW-3	3782187.245	11543464.19	218.64	215.31	2" PVC with 10-foot screen interval	23.33	20	20	8 - 20	West Ash Pond	Downgradient	11/29/2012	No	VPDES
MW-4	3782007.27	11544890.28	221.07	218.00	2" PVC with 10-foot screen interval	26.07	23.5	23	11 - 23	Stormwater Management Pond (Frog Pond)	Downgradient	11/28/2012	No	VPDES
MW-5	3781730.652	11545318.79	218.07	215.39	2" PVC with 10-foot screen interval	22.68	21	20	8 - 20	Stormwater Management Pond (Frog Pond)	Downgradient	11/28/2012	No	VPDES
MW-6	3780998.568	11545361.04	233.29	230.95	2" PVC with 10-foot screen interval	38.34	36	36	24 - 36	East Ash Pond	Downgradient	11/27/2012	Yes	VPDES till MW-19 installed
MW-7	3780653.826	11545868.93	241.94	239.14	2" PVC with 10-foot screen interval	23.8	21	21	9 - 21	East Ash Pond	Downgradient	11/27/2012	Yes	VPDES till MW-20 installed
MW-8	3780461.993	11546325.93	239.78	236.71	2" PVC with 10-foot screen interval	24.07	21	21	8 - 20	East Ash Pond	Downgradient	11/27/2012	Yes	VPDES till MW-21 installed
MW-9	3780849.093	11547317.06	351.91	349.00	2" PVC with 14-foot screen interval	49.91	47	47	31 - 47	North Ash Pond	Downgradient	11/29/2012	No	Dry Well, VPDES
MW-10*	3780999.478	11546362.54	240.10	237.25	2" PVC with 10-foot screen interval	33.85	31	31	19 - 31	North Ash Pond	Downgradient	11/27/2012	Yes	VPDES, use W-3
MW-11	3783128.026	11546850.62	330.52	327.74	2" PVC with 15-foot screen interval	51.78	49	49	32 - 49	Stormwater Management Basin, East Ash Pond, North Ash Pond	Upgradient	11/28/2012	No	VPDES and VSWMR
MW-12**	3782305.43	11542586.74	218.93	216.52	2" PVC with 8-foot screen interval	35.41	33	33	23 - 33	West Ash Pond (deep well)***	Downgradient	12/4/2012	No	VPDES
MW-13	3782386.856	11542133.65	219.07	216.57	2" PVC with 10-foot screen interval	22.5	22.5	21	9 - 21	Metals Pond	Downgradient	11/29/2012	No	VPDES
W-1***	3781224.57	11546622.00	328.62	327.55	1.5" PVC with 10-foot screen interval (hand-slotted)	---	48	48	7 - 48	North Ash Pond	Downgradient	11/22/1983	No	NA
W-2***	3781193.21	11546580.75	336.31	333.86	1.5" PVC with 10-foot screen inteval (hand-slotted)	---	84	84	7 - 84	North Ash Pond	Downgradient	10/11/1983	No	NA
W-3***	3781093.94	11546452.73	274.31	272.94	1.5" PVC with 10-foot screen inteval (hand-slotted)	---	36	36	7 - 36	North Ash Pond	Downgradient	11/22/1983	No	VPDES
MW-14	3781441.19	11544841.04	221.17	218.30	2" PVC with 10-foot screen interval	---	23.2	23.2	11.5 - 22	East Ash Pond	Downgradient	1/28/2015	No	NA
MW-15	3781346.94	11544990.53	221.59	219.00	2" PVC with 10-foot screen interval	---	23.6	23.6	11.5 - 23.6	East Ash Pond, North Ash Pond	Downgradient	1/28/2015	No	VSWMR
MW-16	3780772.566	11545581	232.31	229.30	2" PVC with 10-foot screen interval	27.78	24.8	24.8	13 - 24.8	East Ash Pond	Downgradient	1/29/2015	Yes	NA
MW-17	3780754.94	11545686.07	242.55	239.73	2" PVC with 5-foot screen interval	48.41	45.6	45.6	45.6 - 38.5	East Ash Pond	Downgradient	3/17/2015	Yes	NA
MW-18	3780569.89	11546080.64	239.22	236.31	2" PVC with 5-foot screen interval	46.41	43.5	43.5	36.2 - 43.5	East Ash Pond	Downgradient	3/17/2015	Yes	NA
MW-19	To Be Constructed									East Ash Pond	Downgradient	To Be Constructed	No	VSWMR
MW-20	To Be Constructed									East Ash Pond	Downgradient	To Be Constructed	No	VSWMR
MW-21	To Be Constructed									East Ash Pond	Downgradient	To Be Constructed	No	VSWMR
MW-22	To Be Constructed									East Ash Pond	Downgradient	To Be Constructed	No	VSWMR
MW-23	To Be Constructed									East Ash Pond	Downgradient	To Be Constructed	No	VSWMR
MW-24	To Be Constructed									East Ash Pond, North Ash Pond	Upgradient	To Be Constructed	No	VSWMR
MW-25	To Be Constructed									North Ash Pond	Downgradient	To Be Constructed	No	VSWMR
MW-26	To Be Constructed									North Ash Pond	Downgradient	To Be Constructed	No	VSWMR

Notes:
AMSL = Above Mean Sea Level
* Installed in vicinity of W-3 and screened in natural soils beneath base of pond embankment.
** Installed adjacent to MW-2 and screened in weathered slate.
*** Previously Existing Well
Red text indicates proposed wells to be decommissioned/abandoned
Blue text indicates proposed wells to be installed

Coordinate system is Virginia State Plane South
AMSL = Above Mean Sea Level
VPDES = Virginia Pollutant Discharge Elimination System
VSWMR = Virginia Solid Waste Management Regulations
-- = Not Applicable. These wells are to be considered as acceptable for water level measurements only and were not installed with protocols that would allow water quality sampling

Table 2
Estimated Hydraulic Conductivity
Bremo Power Station
Bremo Bluff, Virginia

Well Identification	Formation	Lithology	Solution Method	Evaluation Method	Hydraulic Conductivity		
					(cm/sec)	(ft/sec)	(ft/day)
MW-3	Overburden	Alluvium/Clay	Bower-Rice	Slug, Rising Head	1.87E-05	6.14E-07	5.30E-02
				Slug, Falling Head	2.09E-05	6.85E-07	5.92E-02
MW-5	Overburden	Alluvium/Clay	Bower-Rice	Slug, Rising Head	4.26E-04	1.40E-05	1.21E+00
				Slug, Falling Head	3.83E-04	1.26E-05	1.09E+00
MW-7	Overburden	Fill	Bower-Rice	Slug, Rising Head	2.10E-04	6.90E-06	5.96E-01
				Slug, Falling Head	2.54E-04	8.32E-06	7.19E-01
MW-11	Overburden	Saprolite	Bower-Rice	Slug, Rising Head	1.82E-04	5.98E-06	5.17E-01
				Slug, Falling Head	5.36E-05	1.76E-06	1.52E-01
				Aquifer Geometric Mean	**1.16E-04**	**3.81E-06**	**3.29E-01**

Notes:

cm/sec =	centimeter per second
ft/min =	feet per minute
ft/day =	feet per day

Table 3
Summary of Sample Container Information and Hold Times
Bremo Power Station
Bremo Bluff, Virginia

Parameter	Container & Volume	Preservative	Maximum Holding Time
Alkalinity	Plastic, 250 mL	None	14 Days
Hardness	Plastic, 500 mL	HNO_3 to pH<2	6 months
Total Organic Carbon	250-500 mL 250 mL	H_2SO_4 to pH<2 HCL to pH<2	28 days
pH	Flow-through cell or plastic, 500 mL	None	15 minutes (field analysis)
Specific Conductance	Flow-through cell or plastic, 500 mL	None	15 minutes (field analysis)
Temperature	Flow-through cell or plastic, 500 mL	None	15 minutes (field analysis)
Mercury (total)	Plastic; 250 mL	HNO_3 to pH<2	28 days
Metals (total) except mercury	Plastic, 250 mL	HNO_3 to pH<2	6 months
Total Dissolved Solids (TDS)	Plastic, 200 mL	None	7 days
Fluoride, Chloride, Sulfate	Plastic, 250 mL	None	28 days
Radium 226/228	Plastic, 1/2 gallon (2 L)	Preserved upon receipt at laboratory	6 months

Notes:
mL= milliliter
L= Liter
HNO_3 = Nitric Acid

Table 4
Summary of Statistical Methods for Databases with Censored Data
Bremo Power Station
Bremo Bluff, Virginia

Percentage of Non-Detects in the Database	Statistical Analysis Method
Less than 25%	Replace NDs with LOD or LOQ then proceed with parametric procedures: Tolerance Limits, Prediction Limits, or Control Charts
25 to 50%	Use Cohen's or Aitchison's adjustment, then proceed with: Tolerance Limits, Prediction Limits, Confidence Intervals, or Control Charts
More than 50%	Proceed with Nonparametric Methods: Tolerance Limits, Prediction Limits, Wilcoxin-Rank Sum Test, or Test of Proportions

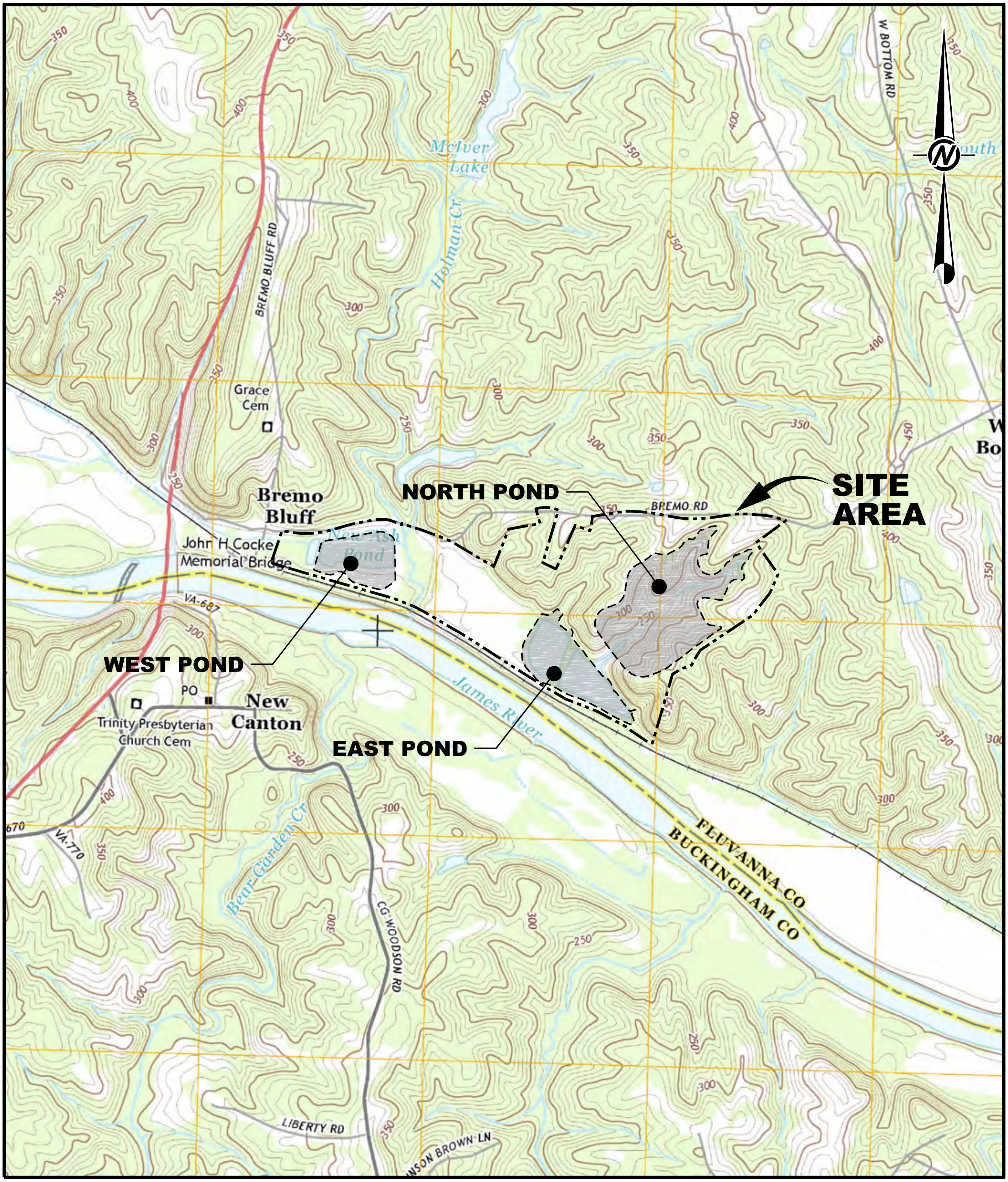
Notes:

ND = Not detect above laboratory detection limit

LOD = Limit of Detection

LOQ = Limit of Quantitation

DRAWINGS



REFERENCE

BASE MAP CONSISTS OF 7.5-MINUTE USGS TOPOGRAPHIC
QUADRANGLE NAMED ARVONIA, VIRGINIA, DATED 2013.

2000 0 2000
SCALE FEET

Golder Associates Richmond, Virginia	DATE 0?/25/15	TITLE	
	DESIGN CJL	SITE LOCATION MAP	
	CADD BPG		
PROJECT No. 15-20347	CHECK CJL		
SCALE AS SHOWN / REV. 0	REVIEW JRD	DOMINION - BREMO POWER STATION	DRAWING 1

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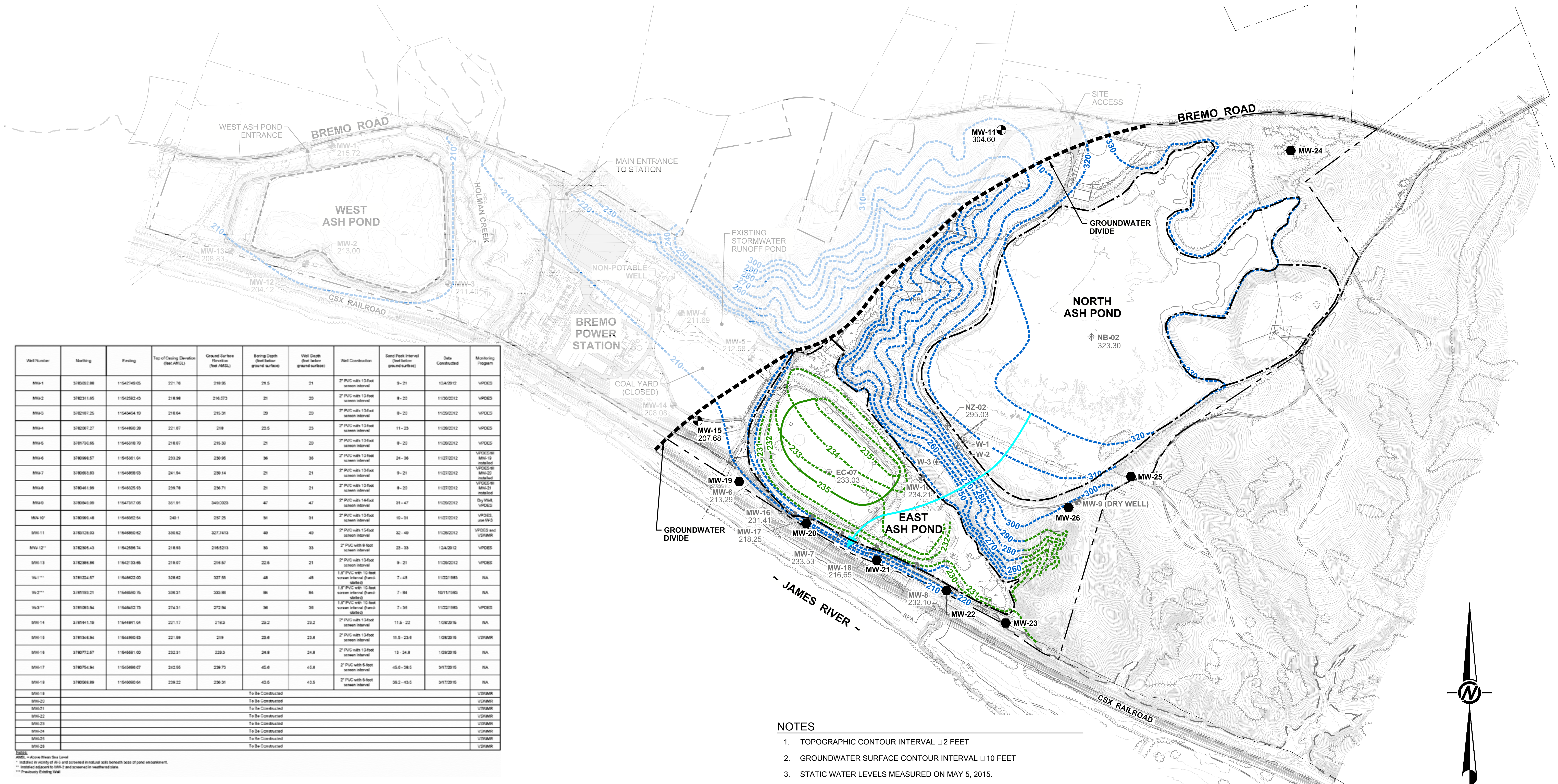

Well Number	Northing	Easting	Top of Casing Elevation (feet AMSL)	Ground Surface Elevation (feet AMSL)	Boring Depth (feet below ground surface)	Well Depth (feet below ground surface)	Well Construction	Sand Pack Interval (feet below ground surface)	Date Constructed	Monitoring Program
MW-1	3783052.88	11542749.05	221.76	218.95	21.5	21	2" PVC with 10-foot screen interval	9 - 21	12/4/2012	VPDES
MW-2	3782311.65	11542582.43	218.98	216.573	21	20	2" PVC with 10-foot screen interval	8 - 20	11/30/2012	VPDES
MW-3	3782187.25	11543464.19	218.64	215.31	20	20	2" PVC with 10-foot screen interval	8 - 20	11/29/2012	VPDES
MW-4	3782007.27	11544890.28	221.07	218	23.5	23	2" PVC with 10-foot screen interval	11 - 23	11/28/2012	VPDES
MW-5	3781730.65	11545318.79	218.07	215.39	21	20	2" PVC with 10-foot screen interval	8 - 20	11/28/2012	VPDES
MW-6	3780998.57	11545361.04	233.29	230.95	36	36	2" PVC with 10-foot screen interval	24 - 36	11/27/2012	VPDES till MW-19 installed
MW-7	3780653.83	11545868.93	241.94	239.14	21	21	2" PVC with 10-foot screen interval	9 - 21	11/27/2012	VPDES till MW-20 installed
MW-8	3780461.99	11546325.93	239.78	236.71	21	21	2" PVC with 10-foot screen interval	8 - 20	11/27/2012	VPDES till MW-21 installed
MW-9	3780849.09	11547317.06	351.91	349.0023	47	47	2" PVC with 14-foot screen interval	31 - 47	11/29/2012	Dry Well, VPDES
MW-10*	3780996.48	11546362.54	240.1	237.25	31	31	2" PVC with 10-foot screen interval	19 - 31	11/27/2012	VPDES, use W-3
MW-11	3783128.03	11546850.62	330.52	327.7413	49	49	2" PVC with 15-foot screen interval	32 - 49	11/28/2012	VPDES and VSWMR
MW-12**	3782505.43	11542586.74	218.93	216.5213	33	33	2" PVC with 8-foot screen interval	23 - 33	12/4/2012	VPDES
MW-13	3782386.86	11542133.65	219.07	216.57	22.5	21	2" PVC with 10-foot screen interval	9 - 21	11/29/2012	VPDES
W-1***	3781224.57	11546622.00	328.62	327.55	48	48	1.5" PVC with 10-foot screen interval (hand-slotted)	7 - 48	11/22/1983	NA
W-2***	3781193.21	11546580.76	336.31	333.86	84	84	1.5" PVC with 10-foot screen interval (hand-slotted)	7 - 84	10/11/1983	NA
W-3***	3781093.94	11546452.73	274.31	272.94	36	36	1.5" PVC with 10-foot screen interval (hand-slotted)	7 - 36	11/22/1983	VPDES
MW-14	3781441.19	11544841.04	221.17	218.3	23.2	23.2	2" PVC with 10-foot screen interval	11.5 - 22	1/28/2015	NA
MW-15	3781346.94	11544990.53	221.59	219	23.6	23.6	2" PVC with 10-foot screen interval	11.5 - 23.6	1/28/2015	VSWMR
MW-16	3780772.67	11545681.00	232.31	229.3	24.8	24.8	2" PVC with 10-foot screen interval	13 - 24.8	1/29/2015	NA
MW-17	3780754.94	11545686.07	242.55	239.73	45.6	45.6	2" PVC with 5-foot screen interval	45.6 - 38.5	3/17/2015	NA
MW-18	3780566.89	11546090.64	239.22	236.31	43.5	43.5	2" PVC with 5-foot screen interval	36.2 - 43.5	3/17/2015	NA
MW-19	To Be Constructed									VSWMR
MW-20	To Be Constructed									VSWMR
MW-21	To Be Constructed									VSWMR
MW-22	To Be Constructed									VSWMR
MW-23	To Be Constructed									VSWMR
MW-24	To Be Constructed									VSWMR
MW-25	To Be Constructed									VSWMR
MW-26	To Be Constructed									VSWMR

Notes:
AMSL = Above Mean Sea Level
* Installed in vicinity of W-3 and screened in natural soils beneath base of pond embankment.
** Installed adjacent to MW-2 and screened in weathered slate.
*** Previously Existing Well

LEGEND

Symbol	Description
— – – —	APPROXIMATE PROPERTY BOUNDARY
	EXISTING TOPOGRAPHIC CONTOURS (2' INTERVALS) (FROM AERIAL SURVEY - SEE NOTE 7)
	WETLANDS
	SURFACE WATER BOUNDARY
W.E. 113.1	SURFACE WATER ELEVATION
	APPROXIMATE LIMITS OF CCR IMPOUNDMENT (CURRENT STATUS)
	APPROXIMATE LIMITS OF CCR IMPOUNDMENT / CCR UNIT BOUNDARY
	LIMITS OF 100-YR FLOOD PLAIN
	GROUNDWATER DIVIDE
MW-30	PROPOSED GROUNDWATER COMPLIANCE WELL LOCATION AND IDENTIFICATION
MW-11 304.60	EXISTING MONITORING WELL PROPOSED FOR INCLUSION WITHIN GROUNDWATER MONITORING NETWORK AND IDENTIFICATION WITH STATIC GROUNDWATER ELEVATION [FEET ABOVE MEAN SEA LEVEL (AMSL)]
MW-4 211.69	EXISTING MONITORING WELL WITH STATIC GROUNDWATER ELEVATION (FEET AMSL)
NB-02 323.30	EXISTING CPT BORING AND GROUNDWATER OBSERVATION WELL (CONSTRUCTED AND ACCEPTABLE FOR WATER LEVEL MEASUREMENTS ONLY) WITH STATIC GROUNDWATER ELEVATION (FEET AMSL)
W-1	EXISTING GROUNDWATER OBSERVATION WELL CONSTRUCTED WITH 1.5-inch PVC CASING (CONSTRUCTED AND ACCEPTABLE FOR WATER LEVEL MEASUREMENTS ONLY)
105	APPROXIMATE GROUNDWATER SURFACE CONTOUR (FEET AMSL)
105	INFERRED GROUNDWATER SURFACE CONTOUR
105	EAST POND PERCHED GROUNDWATER SURFACE CONTOUR
	APPROXIMATE GROUNDWATER FLOW DIRECTION

NOTES

1. TOPOGRAPHIC CONTOUR INTERVAL □2 FEET
2. GROUNDWATER SURFACE CONTOUR INTERVAL □10 FEET
3. STATIC WATER LEVELS MEASURED ON MAY 5, 2015.
4. CPT BORING WATER LEVELS MEASURED IN MARCH 2015, UTILI□ED FOR INTERPRETING WATER TABLE IN ASH PONDS.
5. MW-7, MW-8, MW-10 AND MW-1□ SCREENED WITHIN FILL AND IN HYDRAULIC CONNECTION WITH PERCHED (MOUNDED) GROUNDWATER SURFACE IN EAST ASH POND. MW-12 WATER ELEVATION NOT UTILI□ED FOR INTERPRETATION AS WELL IS SCREENED IN BEDROCK.
□. GROUNDWATER CONTOURS BASED ON LINEAR INTERPOLATION BETWEEN AND E□TRAPOLATION FROM KNOWN DATUM, TOPOGRAPHIC CONTOURS, AND KNOWN FIELD CONDITIONS. THEREFORE, GROUNDWATER CONTOURS MAY NOT REFLECT ACTUAL GROUNDWATER CONDITIONS.
7. GROUNDWATER CONTOUR LINES SHOW THE WATER TABLE SHAPE AND ELEVATION. THESE CONTOURS ARE INFERRED LINES FOLLOWING THE GROUNDWATER SURFACE AT A CONSTANT ELEVATION ABOVE SEA LEVEL. THE GROUNDWATER FLOW DIRECTION IS GENERALLY PERPENDICULAR TO THE GROUNDWATER SURFACE CONTOURS, SIMILAR TO THE RELATIONSHIP BETWEEN SURFACE WATER FLOW AND TOPOGRAPHIC CONTOURS.
8. BASEMAP INFORMATION (e.g., E□ISTING TOPOGRAPHY, ROADS, TREE LINES, FENCE LINES, ETC.) TAKEN FROM AERIAL SURVEY PREPARED BY McKEN□IE SNYDER. DATE OF AERIAL PHOTOGRAPHY: JANUARY 1□, 2015.
9. POTABLE WELL LOCATION IS TO BE CONSIDERED APPRO□IMATE.
10. WELLS SHOWN IN GRAY ARE NOT PROPOSED FOR GROUNDWATER MONITORING WELL NETWORK.

300 0 300 □00
SCALE FEET

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

PROJECT
DOMINION
BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

TITLE
GROUND□ ATER MONITORING PLAN

PROJECT No.		15-20347	FILE No.	1520347E02
DESIGN	CJL	12/03/15	SCALE	AS SHOWN
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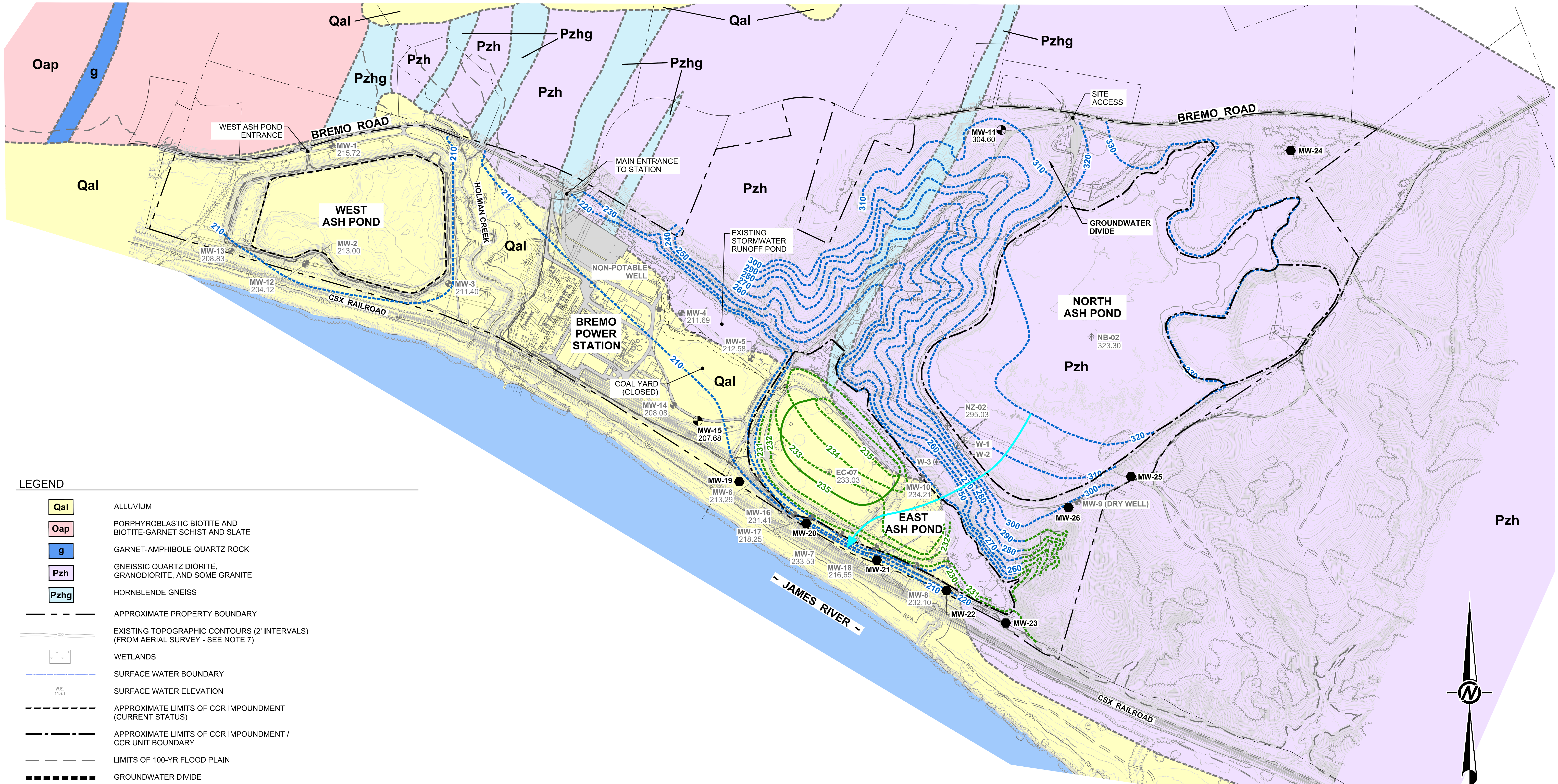
CHECK	CJL	12/03/15	DRA□ ING □	
REVIEW	JRD	12/03/15		

Golder Associates



LEGEND

Qal	ALLUVIUM
Oap	PORPHYROBLASTIC BIOTITE AND BIOTITE-GARNET SCHIST AND SLATE
g	GARNET-AMPHIBOLE-QUARTZ ROCK
Pzh	GNEISSIC QUARTZ DIORITE, GRANODIORITE, AND SOME GRANITE
Pzhg	HORNBLENDE GNEISS
	APPROXIMATE PROPERTY BOUNDARY
	EXISTING TOPOGRAPHIC CONTOURS (2' INTERVALS) (FROM AERIAL SURVEY - SEE NOTE 7)
	WETLANDS
	SURFACE WATER BOUNDARY
W.E. 113.1	SURFACE WATER ELEVATION
	APPROXIMATE LIMITS OF CCR IMPOUNDMENT (CURRENT STATUS)
	APPROXIMATE LIMITS OF CCR IMPOUNDMENT / CCR UNIT BOUNDARY
	LIMITS OF 100-YR FLOOD PLAIN
	GROUNDWATER DIVIDE
MW-30	PROPOSED GROUNDWATER COMPLIANCE WELL LOCATION AND IDENTIFICATION
MW-11 304.60	EXISTING MONITORING WELL PROPOSED FOR INCLUSION WITHIN GROUNDWATER MONITORING NETWORK AND IDENTIFICATION WITH STATIC GROUNDWATER ELEVATION [FEET ABOVE MEAN SEA LEVEL (AMSL)]
MW-4 211.69	EXISTING MONITORING WELL WITH STATIC GROUNDWATER ELEVATION (FEET AMSL)
NB-02 323.30	EXISTING CPT BORING AND GROUNDWATER OBSERVATION WELL (CONSTRUCTED AND ACCEPTABLE FOR WATER LEVEL MEASUREMENTS ONLY) WITH STATIC GROUNDWATER ELEVATION (FEET AMSL)
W-1	EXISTING GROUNDWATER OBSERVATION WELL CONSTRUCTED WITH 1.5-inch PVC CASING (CONSTRUCTED AND ACCEPTABLE FOR WATER LEVEL MEASUREMENTS ONLY)
105	APPROXIMATE GROUNDWATER SURFACE CONTOUR (FEET AMSL)
105	INFERRED GROUNDWATER SURFACE CONTOUR
105	EAST POND PERCHED GROUNDWATER SURFACE CONTOUR
	APPROXIMATE GROUNDWATER FLOW DIRECTION

300 0 300 □00
SCALE FEET

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

PROJECT
DOMINION
BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

TITLE
GEOLOGIC MAP

PROJECT No.		15-20347	FILE No.	1520347E03
DESIGN	CJL	12/03/15	SCALE	AS SHOWN
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CHECK	CJL	12/03/15	DRA□ ING □	
REVIEW	JRD	12/03/15		

Golder Associates

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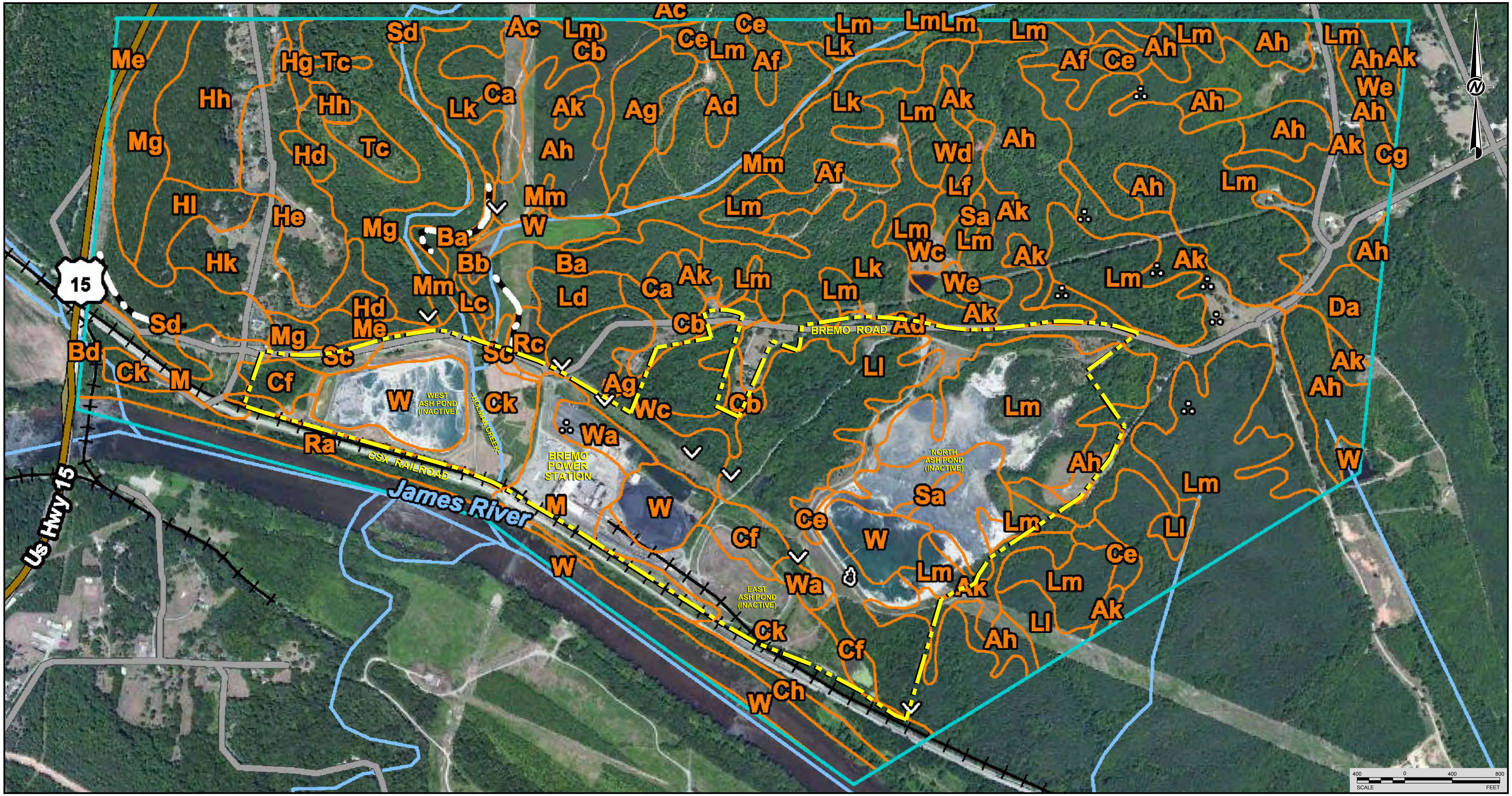

REFERENCE

1. MAP SOURCE: NATURAL RESOURCES CONSERVATION SERVICE
2. SOILS MAP IS GENERATED FROM THE USDA-NRCS CERTIFIED DATA AS OF THE VERSION DATES LISTED BELOW:
   SOIL SURVEY AREA: BUCKINGHAM CO., VA, VERSION 2, DEC. 11, 2013
   SOIL SURVEY AREA: FLUVANNA CO., VA, VERSION 11, DEC. 11, 2013
3. AERIAL IMAGERY SHOWN WAS PHOTOGRAPHED MAY 10, 2010 - JULY 4, 2010.

LEGEND

Ac	Appling fine sandy loam, rolling phase	He	Hiwassee clay loam, eroded undulating phase	Sc	Starr loam
Ad	Appling fine sandy loam, undulating phase	Hg	Hiwassee fine sandy loam, rolling light-colored phase	Sd	Stony land
Af	Appling gritty fine sandy loam, undulating phase	Hh	Hiwassee fine sandy loam, undulating light-colored phase	Tc	Tatum silt loam, undulating phase
Ag	Appling sandy loam, eroded rolling phase	Hk	Hiwassee silt loam, rolling phase	W	Water
Ah	Appling sandy loam, rolling phase	Hl	Hiwassee silt loam, undulating phase	Wa	Wehadkee silt loam
Ak	Appling sandy loam, undulating phase	Lc	Lloyd silt loam, rolling phase	Wc	Wilkes sandy loam, hilly and steep phases
Ba	Bremo silt loam, hilly phase	Ld	Lloyd silt loam, undulating phase	Wd	Wilkes sandy loam, rolling phase
Bb	Bremo silt loam, rolling phase	Lf	Lloyd silty clay loam, eroded undulating phase	We	Worsham sandy loam
Bd	Buncombe loamy fine sandy	Lk	Louisburg sandy loam, eroded rolling and hilly phases		
Ca	Cecil clay loam, eroded rolling phase	Ll	Louisburg sandy loam, eroded steep phase		
Cb	Cecil clay loam, eroded undulating phase	Lm	Louisburg sandy loam, rolling and hilly phases		
Ce	Cecil sandy loam, undulating phase	M	Made land		
Cf	Chewacla silt loam	Me	Manteo silt loam, hilly phase		
Cg	Colfax sandy loam	Mg	Manteo silt loam, steep phase		
Ch	Congaree fine sandy loam	Mm	Mixed alluvial land, well drained		
Ck	Congaree silt loam	Ra	Riverwash		
Da	Durham fine sandy loam, undulating phase	Rc	Rough gullied land		
Hd	Hiwassee clay loam, eroded rolling phase	Sa	Seneca fine sandy loam		

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
0						

PROJECT

DOMINION
BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

TITLE

SOILS MAP

Golder Associates

PROJECT No.		15-20347	FILE No.	1520347E04
DESIGN	CJL	0□/25/15	SCALE	AS SHOWN
CADD	BPG	08/18/15	DRA□ ING □	
CHECK	CJL	12/03/15		
REVIEW	JRD	12/03/15		

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APPENDIX A

BORING AND MONITORING WELL CONSTRUCTION LOGS

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO.: W-1

PROJECT: PHASE II, ASH DISPOSAL MASTER PLAN	SHEET NO. 1 OF 1
CLIENT: VEPCO	JOB NO.: V83016
BORING CONTRACTOR: AYERS & AYERS DRILL: CME 55	ELEVATION: 206 ±

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED	DRIVE	SAMPLER	
					TYPE	S. S.	CASING SIZE: 3¼"
ENCOUNTERED	11-22	–	–	–	DIA.	2" O.D.	DATE START: 11-22-83
AFTER CASING PULLED	11-22	–	–	–	WT.	140 #	DATE FINISHED: 11-22-83
___HR. READING	WATER OBSERVATION WELL INSTALLED				FALL	30"	DRILLER: C. JAMERSON
							INSPECTOR: D. TAIT

STRATUM	DEPTH FT.	ELEV. 206 ±	BLOWS ON SAMPLE SPOON PER 6"	SYMBOL	IDENTIFICATION	REMARKS
	1.5				FINE TO COARSE CLAYEY SILTY SAND, FILL, WITH ROCK FRAGMENTS, MOIST-BROWN, REDDISH BROWN AND TAN (SM)	1½" PVC PIPE INSTALLED TO EL 160
	3.0					BACKFILLED AROUND PIPE TO EL 201 WITH SAND
	5.0					BENTONITE SEAL FROM EL 201 – EL203
		200				4' PROTECTIVE STEEL CASING WITH LOCKING CAP INSTALLED IN CONCRETE AT TOP OF WELL
						TOP OF CASING AT EL 206.3
		190				
		180				
		170				
						BOTTOM 5' OF PIPE SLOTTED
		160				
					BORING TERMINATED AT 48 FEET	

SYMBOLS

CONCRETE

BENTONITE

SAND

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO.: W-2

PROJECT: PHASE II, ASH DISPOSAL MASTER PLAN
CLIENT: VEPCO
BORING CONTRACTOR: AYERS & AYERS, INC.
DRILL: CME 55

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED
ENCOUNTERED	10/11	–	–	–
AFTER CASING PULLED	10/11	–	–	–
___HR. READING	WATER OBSERVATION WELL INSTALLED			

DRIVE	SAMPLER
TYPE	S. S.
DIA.	2" O.D.
WT.	140 #
FALL	30"

SHEET NO. 1 OF 2
JOB NO.: V83016
ELEVATION: 212
CASING SIZE: 3¼"
DATE START: 10-11-83
DATE FINISHED: 10-11-83
DRILLER: J. T. STONE
INSPECTOR: J. MASON

STRATUM	DEPTH FT.	ELEV. 212	BLOWS ON SAMPLE SPOON, PER 6"	SYMBOL	IDENTIFICATION	REMARKS
	3.0	200			FINE TO COARSE CLAYEY SILTY SAND FILL WITH ROCK FRAGMENTS, MOIST – BROWN, REDDISH BROWN AND TAN (SM)	1¼" PVC pipe installed to El 120 Backfilled around pipe to El 197 with sand Bentonite seal from El 197 to El 195 3 ft protective steel casing with locking cap installed in concrete at top of well
	5.0					
		190				
		180				
		170				COMPACTED EMBANKMENT FILL
		160				
		150				
		140				

SYMBOLS

- CONCRETE
- BENTONITE
- SAND

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO.: W-2
PROJECT: PHASE II, ASH DISPOSAL MASTER PLAN		SHEET NO 2 OF 2
CLIENT: VEPCO		JOB NO.: V83016
BORING CONTRACTOR: AYERS & AYERS, INC.		ELEVATION: 212

DEPTH FT.	ELEV.	BLOWS ON SAMPLE SPOON PER 6	SYMBOL	IDENTIFICATION	REMARKS
				FINE TO COARSE CLAYEY SILTY SAND FILL WITH ROCK FRAGMENTS, MOIST - BROWN, REDDISH BROWN AND TAN (SM)	COMPACTED EMBANKMENT FILL
	130				
	120				Bottom 5' of pipe slotted and screened
				BORING TERMINATED AT 84 FT	

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO.: W-3

PROJECT: PHASE II, ASH DISPOSAL MASTER PLAN
CLIENT: VEPCO
BORING CONTRACTOR: AYERS & AYERS
DRILL: CME 55

SHEET NO. 1 OF 1
JOB NO.: V83016
ELEVATION: 150 ±
CASING SIZE: 3¼"
DATE START: 11-22-83
DATE FINISHED: 11-22-83
DRILLER: C. JAMERSON
INSPECTOR: D. TAIT

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED
ENCOUNTERED	11-22	–	–	–
AFTER CASING PULLED	11-22	–	–	–
___HR. READING	WATER OBSERVATION WELL INSTALLED			

DRIVE SAMPLER	
TYPE	S. S.
DIA.	2" O.D.
WT.	140 #
FALL	30"

STRATUM	DEPTH FT.	ELEV. 150 ±	BLOWS ON SAMPLE SPOON PER 6"	SYMBOL	IDENTIFICATION	REMARKS
	1.5				FINE TO COARSE CLAYEY SILTY SAND, FILL, WITH ROCK FRAGMENTS, MOIST-BROWN, REDDISH BROWN AND TAN (SM)	1½" PVC PIPE INSTALLED TO EL 115.5
	4.5					BACKFILLED AROUND PIPE TO EL 143 WITH SAND
	7.0					BENTONITE SEAL FROM EL 143 TO EL 145.5
		140				
		130				4' PROTECTIVE STEEL CASING WITH LOCKING CAP INSTALLED IN CONCRETE AT TOP OF WALL
		120				TOP OF CASING AT EL 150.3
						BOTTOM 5' OF PIPE SLOTTED
					BORING TERMINATED AT 36 FEET	

SYMBOLS

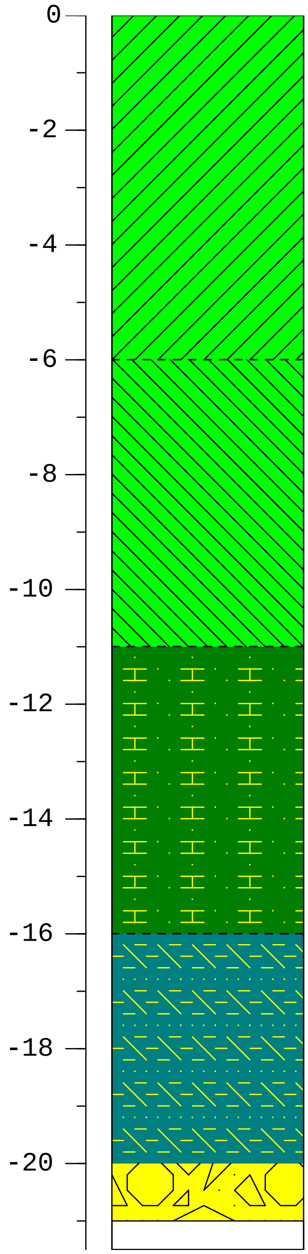
- CONCRETE
- BENTONITE
- SAND

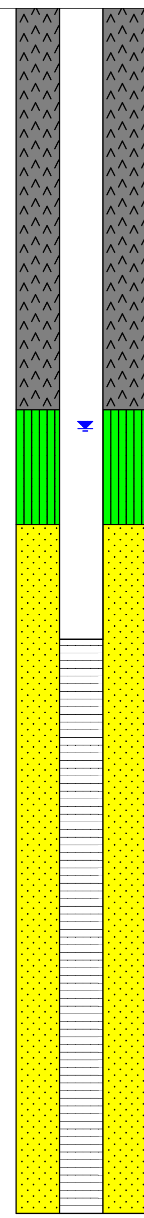
Well Construction Log

Well ID: MW-1

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**21.59 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**HSA**
DATES DRILLED:	**12/4/12 - 1130**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-1**	HAMMER:	**140 LBS**
NORTHING:	**3783032.88**	TOC ELEVATION:	**221.76 ft AMSL**
EASTING:	**11542749.05**	TOG ELEVATION:	**218.95 ft AMSL**

Observed Water Level   N/A = Not Applicable   TOG - Top of Ground   TOC - Top of Casing   AMSL - Above Mean Sea Level





DEPTH	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL MATERIAL NOTES
0 to -6	Silty CLAY, brown, med plastic, moist. CL			Boring diameter 6" PVC Casing: 0' - 11' below grade Grout: 0'-7' below grade
-6 to -11	Lean CLAY with trace silt, wet pockets of moisture, moist. CL		2-1-2-3	Bentonite Seal: 7'-9' below grade
-11 to -16	Clayey SILT with rounded to sub-angular peopples, wet. ML		2-3-4-4	Flush Joint, ATSM F480-88 2 thread Sand Pack DSI #2: 9'-21' below grade
-16 to -20	Clayey SAND, fine to medium grained, sub angular to rounded, poorly sorted. SC		2-4-4-5	PVC Screen 10- slot screen: 11'-21' below grade
-20 to -21	Alluvium deposit of sand and cobbles. GP			
	Auger refusal @ 21.5'		5-16-6-7	

Well Construction Log

Well ID: MW-2

PROJECT INFORMATION

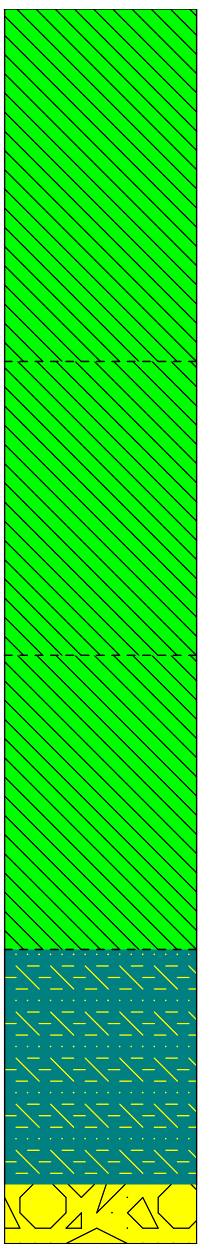
PROJECT:	**1201828**
SITE LOCATION:	**Bremo Bluff, VA**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**
LOGGED BY:	**Seth Christman**
PROJECT MANAGER:	**Tim Davis**
DATES DRILLED:	**11/30/12 - 1130**
WELL ID:	**MW-2**
NORTHING:	**3782311.65**
EASTING:	**11542592.43**

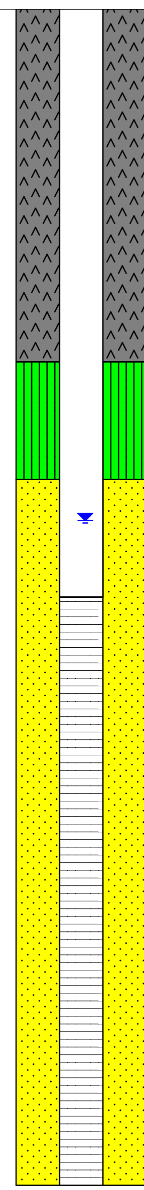
DRILLING INFORMATION

DRILLER:	**Brian Thomas**
BORING DEPTH:	**21.11 feet below grade**
DRILLING CO.:	**Geologic Exploration**
RIG TYPE:	**D-120**
DRILLING METHOD:	**Hollow Stem Auger**
SAMPLING METHODS:	**2 - ft Spit-Spoon Macrocores**
HAMMER:	**140 LBS**
TOC ELEVATION:	**218.98 ft AMSL**
TOG ELEVATION:	**216.57 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES
0		CLAY, tan to grey moltled, non-plastic, dry. CL				Boring diameter 6"
-2						
-4						PVC Casing: 0' - 10' below grade
-6		CLAY, Same as above, slightly plastic, moist.CL		2-3-5-5		Grout: 0'-6' below grade
-8						Bentonite Seal: 6'-8' below grade
-10						Flush Joint, ATSM F480-88 2 thread
-12		Silty CLAY, tan, slightly plastic, wet. CL		3-4-5-7		
-14						Sand Pack DSI #2: 8'-20' below grade
-16		Clayey SAND, fine to medium grained, sub angular to rounded, poorly sorted. SC		3-3-2-2		
-18						PVC Screen 10- slot screen: 10'-20' below grade
-20		Alluvium deposit of sub rounded gravel 1cm to 1" in diameter. GP				





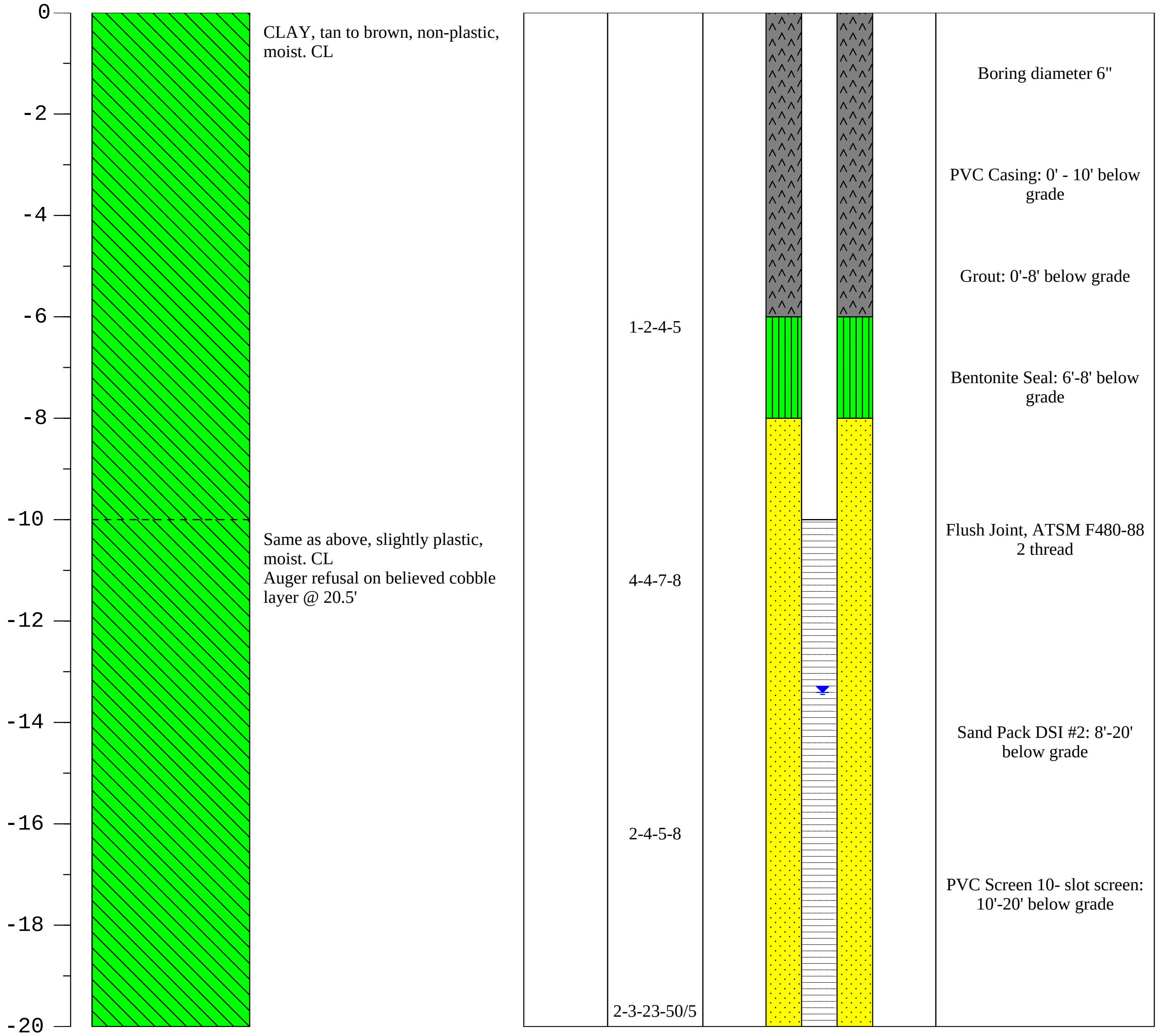
Well Construction Log

Well ID: MW-3

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**19.97 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**HSA**
DATES DRILLED:	**11/29/12 - 1545**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-3**	HAMMER:	**140 LBS**
NORTHING:	**3782187.25**	TOC ELEVATION:	**218.64 ft AMSL**
EASTING:	**11543464.19**	TOG ELEVATION:	**215.31 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES



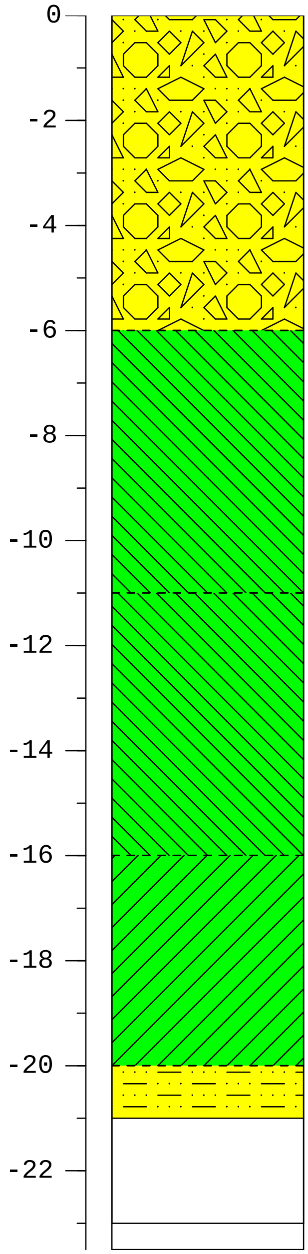
Well Construction Log

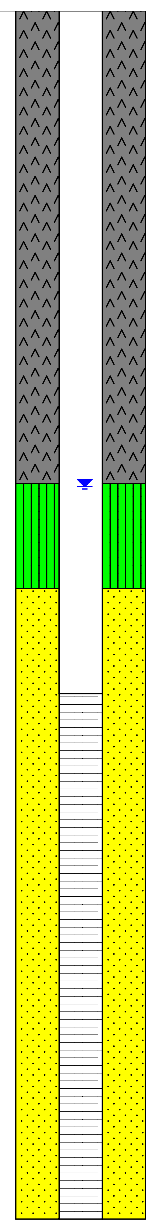
Well ID: MW-4

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**23.65 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**HSA**
DATES DRILLED:	**11/28/12 - 1020**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-4**	HAMMER:	**140 LBS**
NORTHING:	**3782007.27**	TOC ELEVATION:	**221.07 ft AMS**
EASTING:	**11544890.28**	TOG ELEVATION:	**218.00 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES
0		FILL				Boring diameter 6"
						PVC Casing: 0' - 13' below grade
						Grout: 0'-9' below grade
-6		CLAY, grey, lean-plastic, medium stiff. CH		4-10-8-7		
-10						Bentonite Seal: 9'-11' below grade
		CLAY, tan to green moltled, medium plastic, moist. CH		4-2-3-4		
-14						Flush Joint, ATSM F480-88 2 thread
-16		Silty CLAY, red/tan/green moltled, relic foliation, 1mm bedding planes. CL		3-5-6-9		Sand Pack DSI #2: 11'-23' below grade
-20		Sandy SILT, non-plastic, saturated, loose. ML				PVC Screen 10- slot screen: 13'-23' below grade
		Auger refusal @ 23.5'. No recovery.		3-3-2-3		
				50/1		





Well Construction Log

Well ID: MW-5

PROJECT INFORMATION

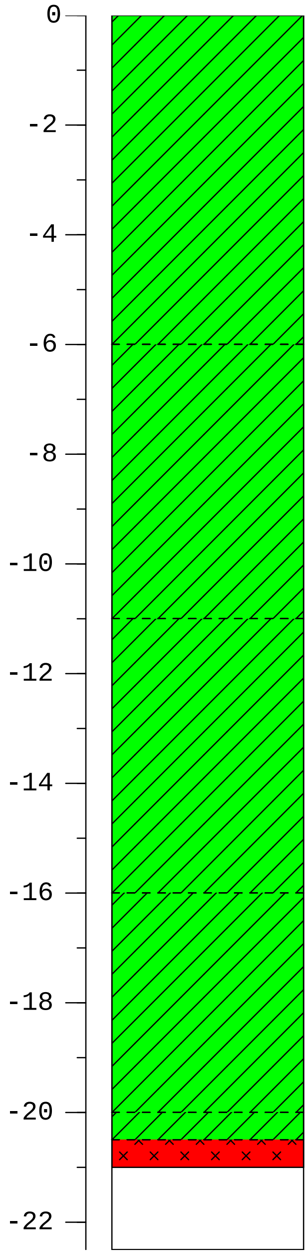
PROJECT:	**1201828**
SITE LOCATION:	**Bremo Bluff, VA**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**
LOGGED BY:	**Seth Christman**
PROJECT MANAGER:	**Tim Davis**
DATES DRILLED:	**11/28/12 - 915**
WELL ID:	**MW-5**
NORTHING:	**3781730.65**
EASTING:	**11545318.79**

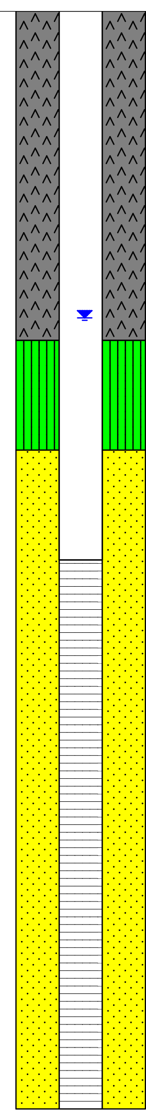
DRILLING INFORMATION

DRILLER:	**Brian Thomas**
BORING DEPTH:	**20.95 feet below grade**
DRILLING CO.:	**Geologic Exploration**
RIG TYPE:	**D-120**
DRILLING METHOD:	**HSA**
SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
HAMMER:	**140 LBS**
TOC ELEVATION:	**218.07 ft AMSL**
TOG ELEVATION:	**215.39 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES
0 to -6		Silty CLAY, tan to brown, non-plastic, moist. CL				Boring diameter 6" PVC Casing: 0' - 10' below grade Grout: 0'-6' below grade
-6 to -11		Silty CLAY with angular gravel, tan to grey, non-plastic, damp. CL		3-3-4-3		Bentonite Seal: 6'-8' below grade Flush Joint, ATSM F480-88 2 thread
-11 to -16		Silty CLAY, grey to tan moltled, non-plastic, damp with moisture pockets. CL		2-4-4-6		Sand Pack DSI #2: 8'-20' below grade
-16 to -20		SAA, saturated. CL		3-3-3-5		PVC Screen 10- slot screen: 10'-20' below grade
-20 to -20.5		SAA, with fine grained sand, well rounded/sorted. SM				
-20.5 to -21		Auger refusal @ 21'. Shards of foliated rock with feldspar, hornblende, biotite, and other fine crystals found in split spoon.		3-3-4-50/4		



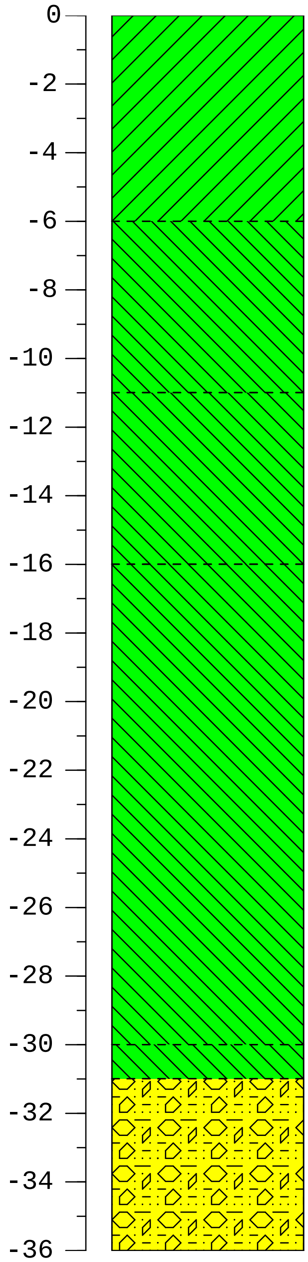


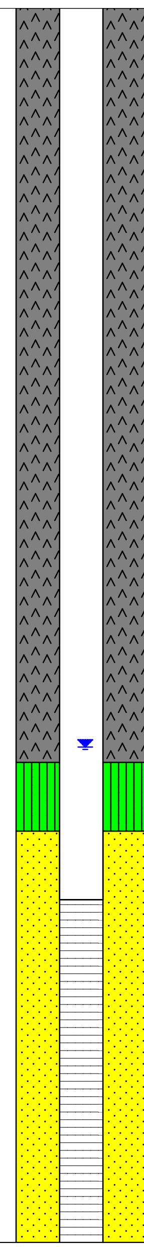
Well Construction Log

Well ID: MW-6

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**35.10 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**HSA**
DATES DRILLED:	**11/27/12 - 1513**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-6**	HAMMER:	**140 LBS**
NORTHING:	**3780998.57**	TOC ELEVATION:	**233.29 ft AMSL**
EASTING:	**11545361.04**	TOG ELEVATION:	**230.95 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level





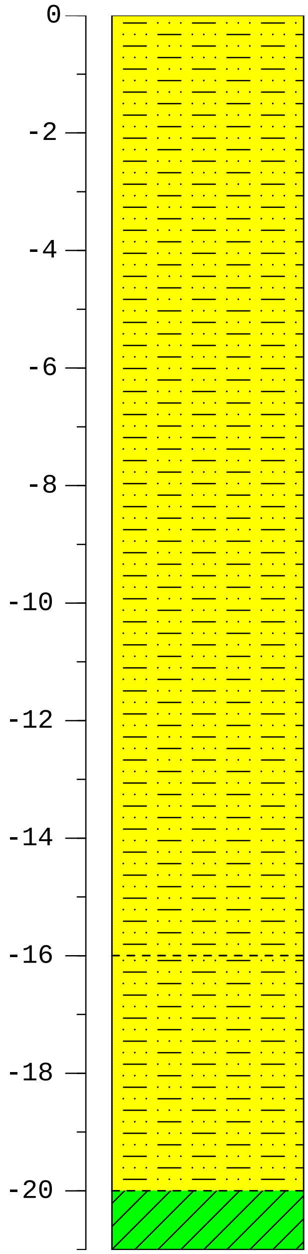
DEPTH	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL MATERIAL NOTES
0	Silty CLAY with rock frags, orange to brown, dry, stiff. CL			Boring diameter 6"
-4				PVC Casing: 0' - 22' below grade
-6	Clay with trace silt, red, med plastic, dry stiff. CH		3-5-6-8	
-11	CLAY, brown to tan, med plastic, dry, stiff. CH		4-4-6-9	
-16	CLAY, with rock frags, dry, very stiff. CH		4-4-7-8	Grout: 0'-22' below grade
-21			4-5-8-11	
-23				Bentonite Seal: 22'-24' below grade
-26			5-7-10-12	Flush Joint, ATSM F480-88 2 thread
-30	CLAY, wet. CH			
-31	GRAVEL and SAND, rounded to angular, poorly sorted, alluvium, wet. GP		4-4-4-4	PVC Screen 10- slot screen: 26'-36' below grade
-34				Sand Pack DSI #2: 24'-36' below grade

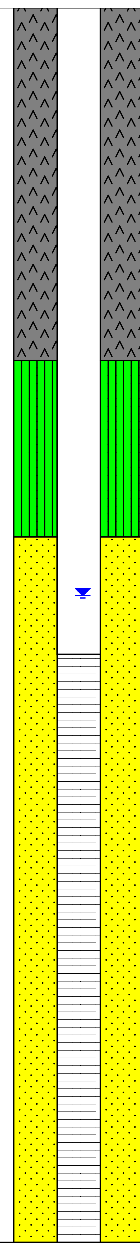
Well Construction Log

Well ID: MW-7

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**21.96 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**Hollow Stem Auger**
DATES DRILLED:	**11/27/12 - 835**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-7**	HAMMER:	**140 LBS**
NORTHING:	**3780653.83**	TOC ELEVATION:	**241.94 ft AMSL**
EASTING:	**11545868.93**	TOG ELEVATION:	**239.14 ft AMSL**

Observed Water Level   N/A = Not Applicable   TOG - Top of Ground   TOC - Top of Casing   AMSL - Above Mean Sea Level





DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES
0		Sandy SILT, fine grained, gray to black, non-plastici, dry, loose. ML				Boring diameter 6"
-2						
-4						PVC Casing: 0' - 11' below grade
						Grout: 0'-7' below grade
-6				4-4-3-6		
-8						Bentonite Seal: 7'-9' below grade
-10						
				2-1-1-2		Flush Joint, ATSM F480-88 2 thread
-12						
-14						Sand Pack DSI #2: 9'-21' below grade
-16		Sandy SILT, with trace clay, plastic, saturated. ML		1-1-1		
						PVC Screen 10- slot screen: 11'-21' below grade
-18						
-20		Silty CLAY, dry, some structure. CL				

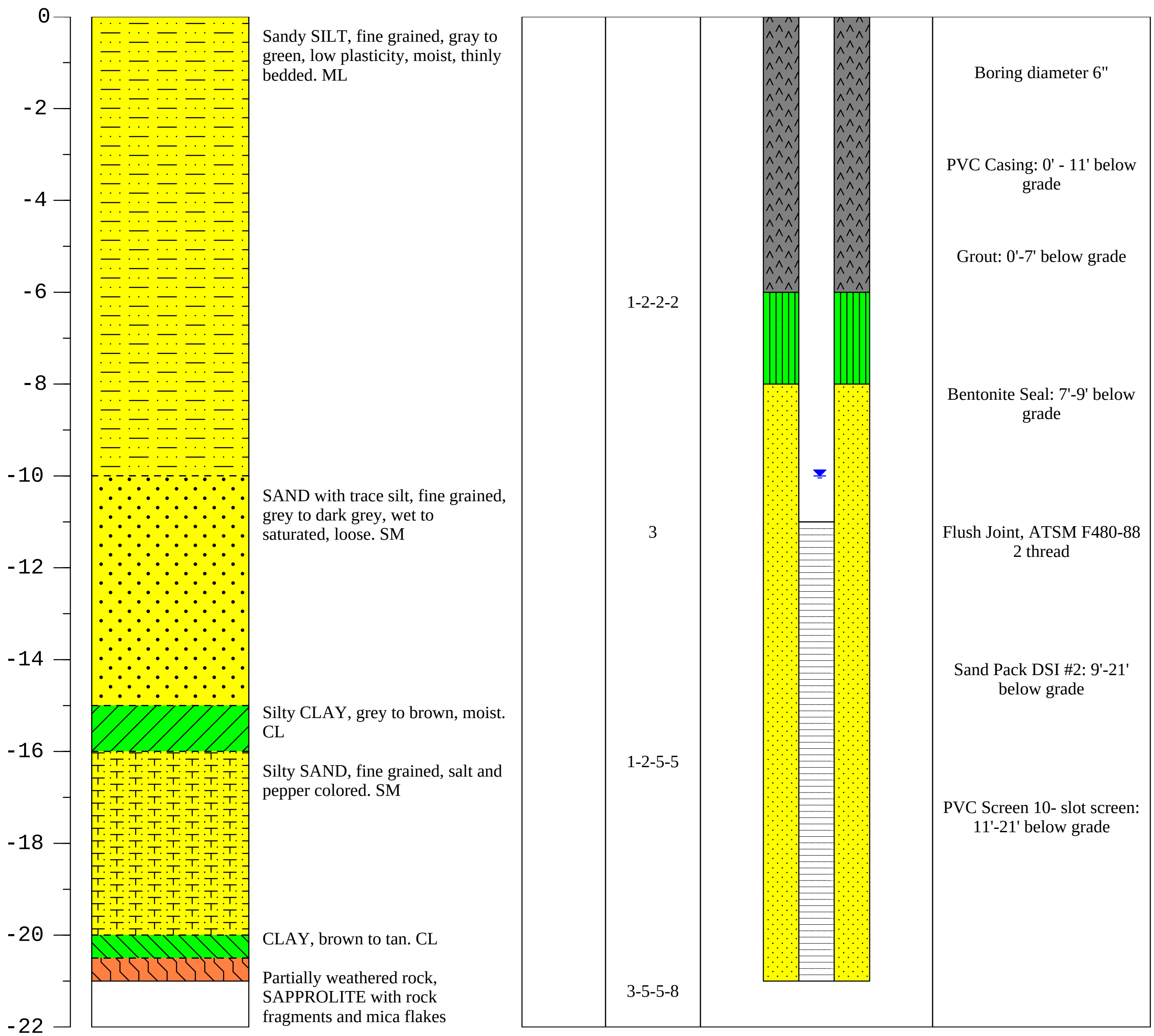
Well Construction Log

Well ID: MW-8

PROJECT INFORMATION	
PROJECT:	**1201828**
SITE LOCATION:	**Bremo Bluff, VA**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**
LOGGED BY:	**Seth Christman**
PROJECT MANAGER:	**Tim Davis**
DATES DRILLED:	**11/27/12 - 1400**
WELL ID:	**MW-8**
NORTHING:	**3780461.99**
EASTING:	**11546325.93**

DRILLING INFORMATION	
DRILLER:	**Brian Thomas**
BORING DEPTH:	**22.55 feet below grade**
DRILLING CO.:	**Geologic Exploration**
RIG TYPE:	**D-120**
DRILLING METHOD:	**HSA**
SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
HAMMER:	**140 LBS**
TOC ELEVATION:	**239.78 ft AMSL**
TOG ELEVATION:	**236.71 ft AMSL**

Observed Water Level   N/A = Not Applicable   TOG - Top of Ground   TOC - Top of Casing   AMSL - Above Mean Sea Level



DEPTH	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL MATERIAL NOTES
0 to -10	Sandy SILT, fine grained, gray to green, low plasticity, moist, thinly bedded. ML		1-2-2-2	Boring diameter 6" PVC Casing: 0' - 11' below grade Grout: 0'-7' below grade Bentonite Seal: 7'-9' below grade
-10 to -15	SAND with trace silt, fine grained, grey to dark grey, wet to saturated, loose. SM		3	Flush Joint, ATSM F480-88 2 thread Sand Pack DSI #2: 9'-21' below grade
-15 to -16	Silty CLAY, grey to brown, moist. CL			
-16 to -20	Silty SAND, fine grained, salt and pepper colored. SM		1-2-5-5	PVC Screen 10- slot screen: 11'-21' below grade
-20 to -20.5	CLAY, brown to tan. CL			
-20.5 to -21	Partially weathered rock, SAPPROLITE with rock fragments and mica flakes		3-5-5-8	

Well Construction Log

Well ID: MW-9

PROJECT INFORMATION

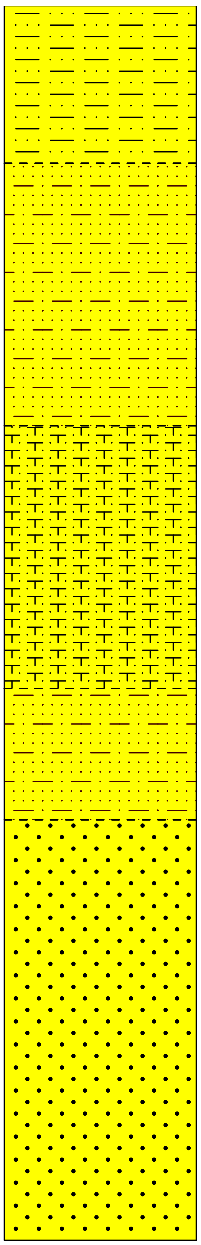
PROJECT:	**1201828**
SITE LOCATION:	**Bremo Bluff, VA**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**
LOGGED BY:	**Seth Christman**
PROJECT MANAGER:	**Tim Davis**
DATES DRILLED:	**11/29/12 - 930**
WELL ID:	**MW-9**
NORTHING:	**3780849.09**
EASTING:	**11547317.06**

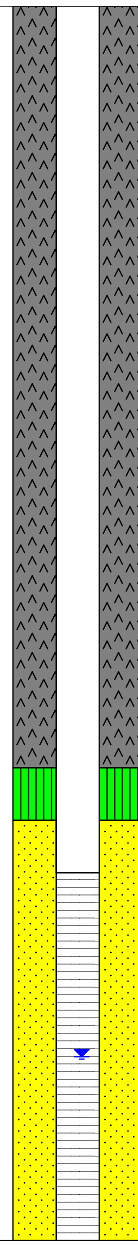
DRILLING INFORMATION

DRILLER:	**Brian Thomas**
BORING DEPTH:	**47.29 feet below grade**
DRILLING CO.:	**Geologic Exploration**
RIG TYPE:	**D-120**
DRILLING METHOD:	**HSA**
SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
HAMMER:	**140 LBS**
TOC ELEVATION:	**351.91 ft AMSL**
TOG ELEVATION:	**349.00 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES
0 to -6		Sandy SILT, fine grained, tan, non-plastic, damp. ML				Boring diameter 6"
-6 to -16		SILT and SAND, fine grained, sub angular to angular, red to tan, quartz and hornblende minerals seen. ML		3-3-4-6 3-4-4-5		PVC Casing: 0' - 33' below grade Grout: 0'-29' below grade
-16 to -26		Silty SAND, fine grainded, sub-angular to angular trace gravel composed of quartz, feldspar, hornblende, and muscovite. SM		5-6-5-7 5-9-10-13		
-26 to -31		SAND and SILT, fine grained, sub-angular to rounded, massive bedding, sapprolite.		9-13-16-15		Bentonite Seal: 29'-31' below grade
-31 to -47		SAND, fine grained, composed of rock frags of quartz, felspar, and hornblende, dry, very stiff, thinly bedded with foiliated texture. sapprolite. Auger Refusal @ 47'		15/30-50/5 48-50/3 45-50/3 50/4		Flush Joint, ATSM F480-88 2 thread PVC Screen 10- slot screen: 33'-47' below grade Sand Pack DSI #2: 31'-47' below grade





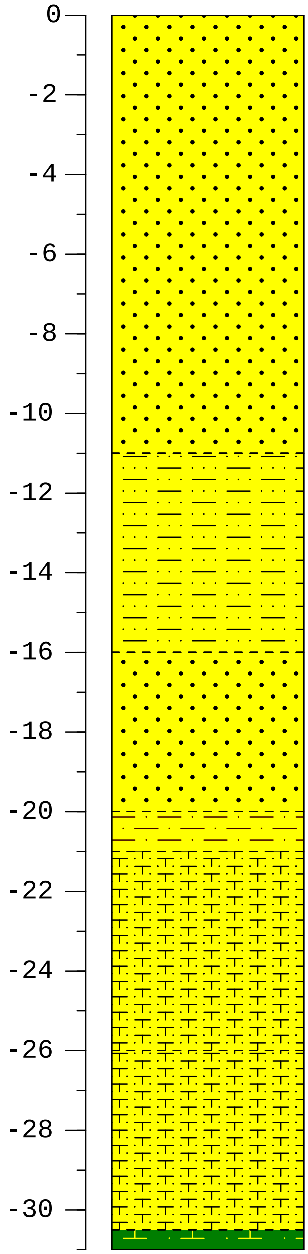
Well Construction Log

Well ID: MW-10

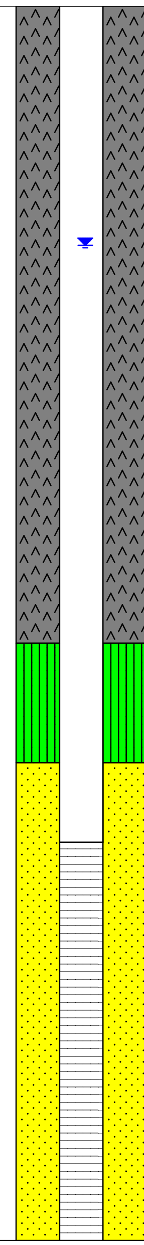
PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**31.15 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**HSA**
DATES DRILLED:	**11/27/12 -1030**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-10**	HAMMER:	**140 LBS**
NORTHING:	**3780999.48**	TOC ELEVATION:	**240.10 ft AMSL**
EASTING:	**11546362.54**	TOG ELEVATION:	**237.25 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES



SOIL DESCRIPTION	NOTES (bls)	WELL MATERIAL NOTES
SAND with trace silt, fine grained, well sorted, red to tan, moist. SW	3-2-1-3	Boring diameter 6" PVC Casing: 0' - 21' below grade Grout: 0'-17' below grade Bentonite Seal: 17'-19' below grade
Silty SAND, fine grained, med sorted, thinly bedded	2-2-1-2	Sand Pack DSI #2: 19'-31' below grade
SAND with trace silt, coarse grained, saturated. SW	1-1-1	
SILT with sand, black, slightly plastic. ML		
Silty SAND with mica and rock frags, fine grained, poorly sorted, wet. SM	3-3-6-8	Flush Joint, ATSM F480-88 2 thread
Silty SAND with rock frags, coarse grained, poorly sorted, hard, wet. SM	2-1-2-3	PVC Screen 10- slot screen: 21'-31' below grade
CLAY and SILT with rock frags and pebbles. SM		



Well Construction Log

Well ID: MW-11

PROJECT INFORMATION

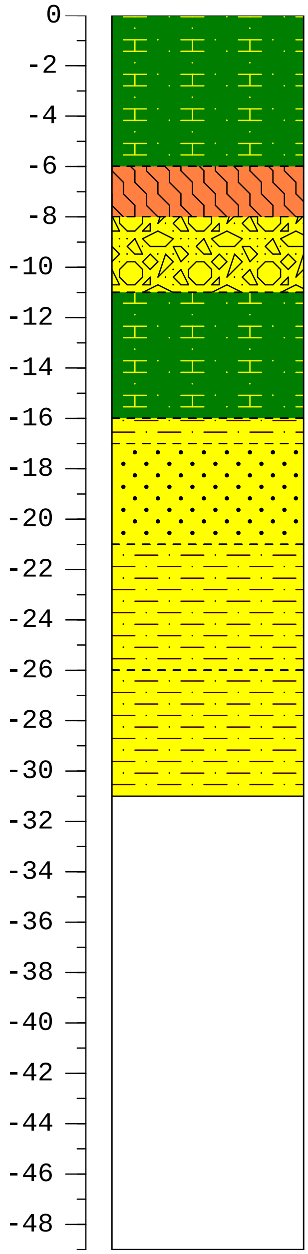
PROJECT:	**1201828**
SITE LOCATION:	**Bremo Bluff, VA**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**
LOGGED BY:	**Seth Christman**
PROJECT MANAGER:	**Tim Davis**
DATES DRILLED:	**11/28/12 -1350**
WELL ID:	**MW-11**
NORTHING:	**3783128.03**
EASTING:	**11546850.62**

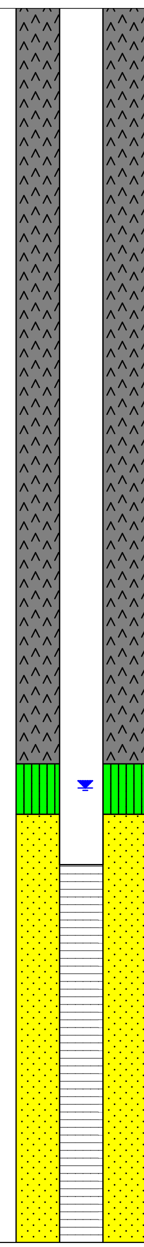
DRILLING INFORMATION

DRILLER:	**Brian Thomas**
BORING DEPTH:	**49.27 feet below grade**
DRILLING CO.:	**Geologic Exploration**
RIG TYPE:	**D-120**
DRILLING METHOD:	**HSA**
SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
HAMMER:	**140 LBS**
TOC ELEVATION:	**330.52 ft AMSL**
TOG ELEVATION:	**327.74 ft AMSL**

Observed Water Level   N/A = Not Applicable   TOG - Top of Ground   TOC - Top of Casing   AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES
0 to -6		Clayey SILT, slightly plastic. ML				Boring diameter 6"
-6 to -8		High relic structure of parent rock, foliated layers, non-plastic, dense.		7-27-36-43		
-8 to -11		Granodiorite rock frags, angular.				PVC Casing: 0' - 34' below grade
-11 to -16		Clayey SILT, red to tan, non-plastic, dry, phylitic texture, hard. ML		5-20-16-17		Grout: 0'-30' below grade
-16 to -19		SILT with fine grains of quartz, feldspar, and mica, non-plastic, moist. ML		9-16-17-23		
-19 to -25		SAND, fine to medium grained, sub-angular to rounded, poorly sorted, quartz, hornblende, muscovite, and feldspar minerals present. SP *Gravel Layer @ 20.8'		10-13-11-7		
-25 to -29		SILT with mica and trace rock frags, red/tan to dark grey, banded foliation. ML		9-12-16-15		
-29 to -31		SILT with trace sand and rock frags, non-plastic, dry, foliated. ML		16-50/4		Bentonite Seal: 30'-32' below grade
-32 to -49		Dence material, saturated. No recovery.		16-50/4 16-50/4		Flush Joint, ATSM F480-88 2 thread PVC Screen 10- slot screen: 34'-49' below grade Sand Pack DSI #2: 32'-49' below grade





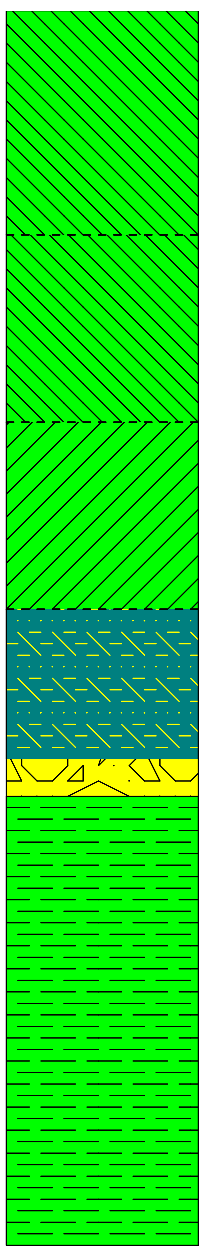
Well Construction Log

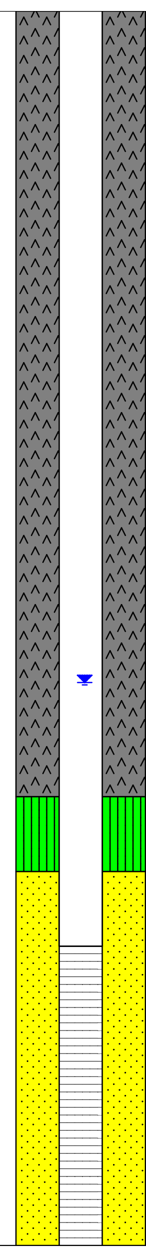
Well ID: MW-12

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**33.23 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**HSA**
DATES DRILLED:	**12/4/12 -900**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-12**	HAMMER:	**140 LBS**
NORTHING:	**3782305.43**	TOC ELEVATION:	**218.93 ft AMSL**
EASTING:	**11542586.74**	TOG ELEVATION:	**216.52 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level

DEPTH	SOIL SYMBOLS	SOIL DESCRIPTION	PID (ppm)	NOTES (bls)	WELL CONSTRUCTION	WELL MATERIAL NOTES
0		CLAY, tan to grey moltled, non-plastic, dry. CL				Boring diameter 6"
-2						
-4						Grout: 0'-21' below grade
-6		SAA, slightly plastic, moist.CL		2-3-5-5		
-8						
-10						
-12		Silty CLAY, tan, slightly plastic, wet. CL		3-4-5-7		PVC Casing: 0' - 25' below grade
-14						
-16		Clayey SAND, fine to medium grained, sub angular to rounded, poorly sorted. SC		3-3-2-2		
-18						
-20		Alluvium deposit of sub rounded gravel 1cm to 1" in diameter. GP				
-22		Weathered SLATE with small garnet crystals, "Arrovian Slate", dry.		1-2-19-20		Bentonite Seal: 21'-23' below grade
-24						
-26				9-50/2		Flush Joint, ATSM F480-88 2 thread
-28						
-30						Sand Pack DSI #2: 23'-33' below grade
-32				50/6		



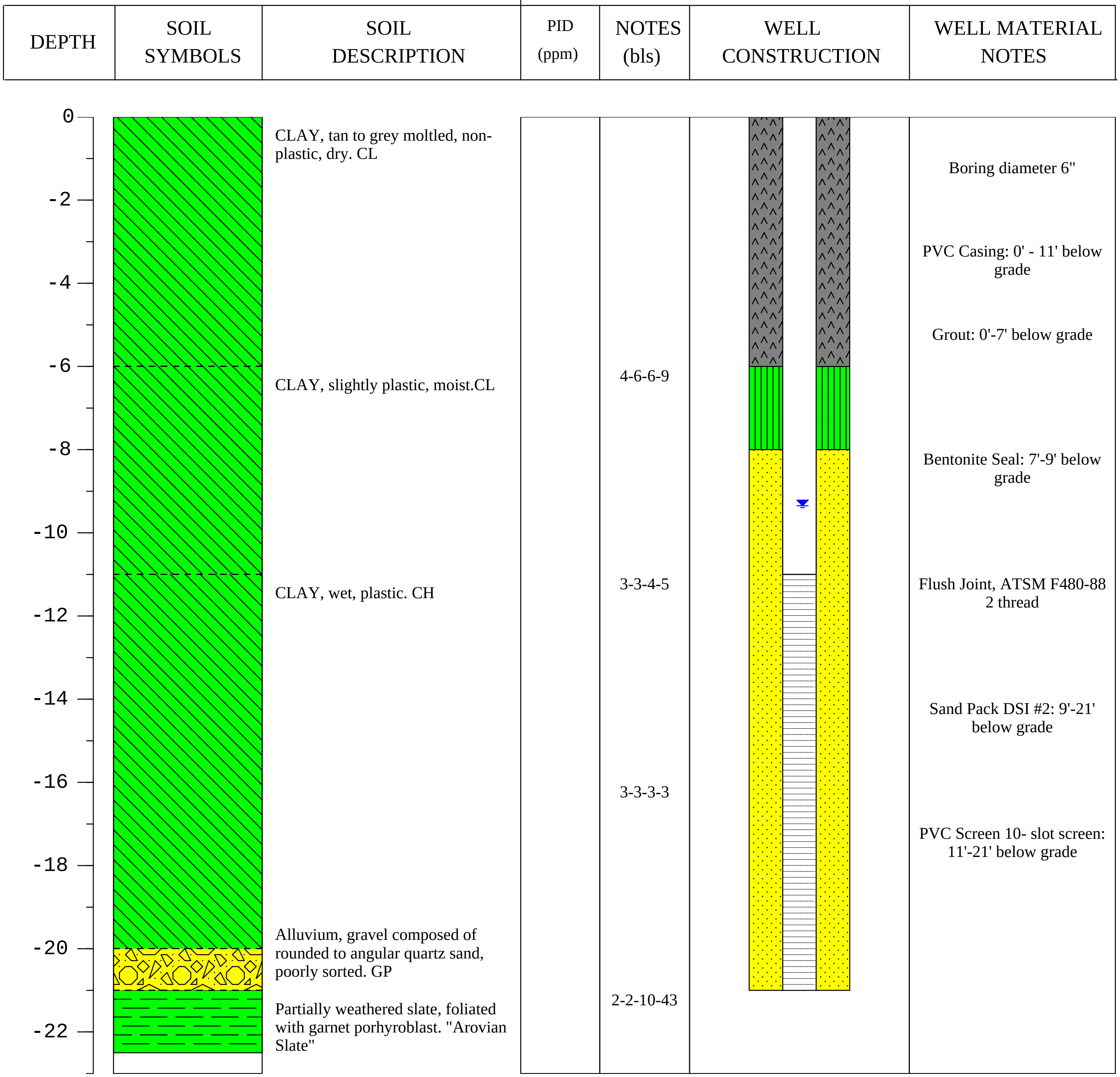


Well Construction Log

Well ID: MW-13

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**1201828**	DRILLER:	**Brian Thomas**
SITE LOCATION:	**Bremo Bluff, VA**	BORING DEPTH:	**22.41 feet below grade**
JOB NAME:	**Dominion - Bremo Bluff Pwr Stn**	DRILLING CO.:	**Geologic Exploration**
LOGGED BY:	**Seth Christman**	RIG TYPE:	**D-120**
PROJECT MANAGER:	**Tim Davis**	DRILLING METHOD:	**HSA**
DATES DRILLED:	**11/29/12 -925**	SAMPLING METHODS:	**2ft Spit-Spoon Macrocores**
WELL ID:	**MW-13**	HAMMER:	**140 LBS**
NORTHING:	**3782386.86**	TOC ELEVATION:	**219.07 ft AMSL**
EASTING:	**11542133.65**	TOG ELEVATION:	**216.57 ft AMSL**

Observed Water Level N/A = Not Applicable TOG - Top of Ground TOC - Top of Casing AMSL - Above Mean Sea Level



HALEY & ALDRICH

GEOPROBE REPORT

Boring No. MW-14

Project	BREMO POWER STATION, BREMO BLUFF, VIRGINIA
Client	DOMINION RESOURCE SERVICES, Inc.
Contractor	FISHBURNE DRILLING

File No.	41740-000
Sheet No.	1 of 2
Start	28 January 2015
Finish	28 January 2015
Driller	J. Rausio
H&A Rep.	R. Mayer
Elevation	218.3 (est.)
Datum	
Location	See Plan N 3781441.185 E 11544841.04

	Casing	Sampler	Barrel
Type	HSA	S	-
Inside Diameter (in.)	4 1/4	1 3/8	-
Hammer Weight (lb)	-	140	-
Hammer Fall (in.)	-	30	-

Drilling Equipment and Procedures

- Rig Make & Model: CME 55
- Bit Type: Cutting Head
- Drill Mud: None
- Casing: HSA Spun to
- Hoist/Hammer: Cat-Head Safety Hammer
- PID Make & Model: MiniRAE 2000

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	Well Diagram	Stratum Change Elev/Depth (ft)	USCS Symbol	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Color, GROUP NAME, max. particle size*, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0							Hand, clear to 4.0 ft, GRAVEL to 1.0 ft										
	4 5	S1 12	4.0 5.0			CL	CLAY (CL), mps 2 mm, no structure, no odor, moist -FILL-										
5					213.3 5.0												
	2 6 7 8	S2 22	8.0 10.0			CL	Stiff yellow brown silty CLAY (CL), mps 2 mm, no structure, no odor, dry -ALLUVIUM-				5	15	80				
10																	
	2 5 5 4	S3 24	13.0 15.0			CL	Stiff yellow brown and light gray silty CLAY (CL), mps 2 mm, mottled, no odor, micaceous, moist -ALLUVIUM-										
15					202.3 16.0												
	1 2 2 3	S4 12	18.0 20.0			ML	Medium stiff yellow brown and tan sandy SILT (ML), mps 5 mm, mottled, no odor, micaceous, wet -ALLUVIUM-			5	15	20	60				
20																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth (ft) to: Bottom of Casing	Bottom of Hole	Water
1/28/15	1200	0	0	23.2	18.0
1/29/15	1200	24	23.2	23.2	10

Sample ID
- O - Open End Rod
- T - Thin Wall Tube
- U - Undisturbed Sample
- S - Splitspoon Sample
- G - Geoprobe

Well Diagram
- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary
- Overburden (ft) 23.2
- Rock Cored (ft) -
- Samples 5S

Boring No. MW-14

Field Tests:
Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High V - Very High

*** Note: Maximum particle size is determined by direct observation within the limitations of sampler size.**

Note: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

HALEY & ALDRICH

GEOPROBE REPORT

Boring No. MW-14
File No. 41740-000
Sheet No. 2 of 2

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	Well Diagram	Stratum Change Elev/Depth (ft)	USCS Symbol	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Color, GROUP NAME, max. particle size*, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
20					197.8 20.5	SM	Very dense gray silty SAND (SM), mps 10 mm, no structure, no odor, wet -ALLUVIUM-		5	5	10	40	40				
	26 50/2	S5 4	22.5 23.2		195.1 23.2		BOTTOM OF EXPLORATION 23.2 FT										

NOTE: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

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GEOPROBE REPORT

Boring No. MW-15

Project	BREMO POWER STATION, BREMO BLUFF, VIRGINIA
Client	DOMINION RESOURCE SERVICES, Inc.
Contractor	FISHBURNE DRILLING

File No.	41740-000
Sheet No.	1 of 2
Start	28 January 2015
Finish	28 January 2015
Driller	J. Rausio
H&A Rep.	R. Mayer
Elevation	219.0 (est.)
Datum	
Location	See Plan N 3781346.941 E 11544990.53

	Casing	Sampler	Barrel
Type	HSA	S	-
Inside Diameter (in.)	4 1/4	1 3/8	-
Hammer Weight (lb)	-	140	-
Hammer Fall (in.)	-	30	-

Drilling Equipment and Procedures

- Rig Make & Model: CME 55
- Bit Type: Cutting Head
- Drill Mud: None
- Casing: HSA Spun to
- Hoist/Hammer: Cat-Head Safety Hammer
- PID Make & Model: MiniRAE 2000

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	Well Diagram	Stratum Change Elev/Depth (ft)	USCS Symbol	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Color, GROUP NAME, max. particle size*, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Dilatancy	Toughness	Plasticity	Strength
0							Hand, clear to 4.0 ft, GRAVEL to 1.0 ft										
	4 4	S1 12	4.0 5.0		214.0 5.0	CL	Medium stiff gray silty CLAY (CL), mps 2 mm, no structure, no odor, micaceous, moist -FILL-										
5																	
	3 3 4 6	S2 22	8.0 10.0			CL	Stiff brown light gray and tan silty CLAY (CL), mps 5 mm, mottled, no odor, moist with moisture pockets				5	15	80				
10																	
	2 4 5 6	S3 24	13.0 15.0			CL	Stiff yellow brown silty CLAY (CL), mps 2 mm, no structure, no odor, wet -ALLUVIUM-										
15																	
	3 3 5 6	S4 24	18.0 20.0		199.5 19.5												
20																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth (ft) to: Bottom of Casing	Bottom of Hole	Water
1/28/15	1600	0	0	23.6	13.0
1/29/15	1600	24	23.6	23.6	11.4

Sample ID

- O - Open End Rod
- T - Thin Wall Tube
- U - Undisturbed Sample
- S - Splitspoon Sample
- G - Geoprobe

Well Diagram

- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary

Overburden (ft)	23.6
Rock Cored (ft)	-
Samples	4S

Boring No. MW-15

Field Tests:
Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High V - Very High

*** Note: Maximum particle size is determined by direct observation within the limitations of sampler size.**

Note: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

HALEY & ALDRICH

GEOPROBE REPORT

Boring No. MW-15
File No. 41740-000
Sheet No. 2 of 2

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	Well Diagram	Stratum Change Elev/Depth (ft)	USCS Symbol	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Color, GROUP NAME, max. particle size*, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
20						ML	Medium stiff yellow brown and tan sandy SILT (ML), mps 5 mm, mottled, no odor, wet -ALLUVIUM-			5	15	20	60				
					195.4 23.6		BOTTOM OF EXPLORATION 23.6 FT										

NOTE: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

Boring No. MW-15

HALEY & ALDRICH

GEOPROBE REPORT

Boring No. MW-16

Project	BREMO POWER STATION, BREMO BLUFF, VIRGINIA
Client	DOMINION RESOURCE SERVICES, Inc.
Contractor	FISHBURNE DRILLING

File No. 41740-000
Sheet No. 1 of 2
Start 29 January 2015
Finish 29 January 2015
Driller J. Rausio
H&A Rep. R. Mayer
Elevation 229.3 (est.)
Datum
Location See Plan
N 3780772.566
E 11545581

	Casing	Sampler	Barrel
Type	HSA	S	-
Inside Diameter (in.)	4 1/4	1 3/8	-
Hammer Weight (lb)	-	140	-
Hammer Fall (in.)	-	30	-

Drilling Equipment and Procedures
Rig Make & Model: CME 55
Bit Type: Cutting Head
Drill Mud: None
Casing: HSA Spun to
Hoist/Hammer: Cat-Head Safety Hammer
PID Make & Model: MiniRAE 2000

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	Well Diagram	Stratum Change Elev/Depth (ft)	USCS Symbol	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Color, GROUP NAME, max. particle size*, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Dilatancy	Toughness	Plasticity	Strength
0							Hand, clear to 4.0 ft, GRAVEL to 1.0 ft										
	3 4	S1 12	4.0 5.0			CH	Medium stiff brown fat CLAY (CH), mps 2 mm, no structure, no odor, moist -FILL-										
5					223.3 6.0												
	2 3 4 4	S2 20	8.0 10.0			CL	Medium stiff gray silty CLAY (CL), mps 10 mm, no structure, no odor, moist to wet, trace roots, and angular quartz fragments		5	5	5	15	70				
10																	
	2 2 7 4	S3 12	13.0 15.0			CL	Similar to S2 except, stiff -ALLUVIUM-										
15					213.3 16.0	ML	Medium stiff gray sandy SILT (ML), mps 10 mm, no structure, no odor, wet -ALLUVIUM-			5	15	20	60				
	1 1 2 3	S4 8	18.0 20.0														
20																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth (ft) to: Bottom of Casing	Bottom of Hole	Water
1/29/15	1700	0	0	24.8	18.0
1/30/15	1200	24	24.8	1.5	

Sample ID
O - Open End Rod
T - Thin Wall Tube
U - Undisturbed Sample
S - Splitspoon Sample
G - Geoprobe

Well Diagram
Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary
Overburden (ft) 24.8
Rock Cored (ft) -
Samples 5S

Boring No. MW-16

Field Tests:
Dilatancy: R - Rapid S - Slow N - None
Toughness: L - Low M - Medium H - High
Plasticity: N - Nonplastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High V - Very High

*** Note: Maximum particle size is determined by direct observation within the limitations of sampler size.**
Note: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

GEOPROBE REPORT

HALEY & ALDRICH

Boring No. MW-16
File No. 41740-000
Sheet No. 2 of 2

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	Well Diagram	Stratum Change Elev/Depth (ft)	USCS Symbol	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Color, GROUP NAME, max. particle size*, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
20																	
	3 4 6 7	S5 22	23.0 25.0		206.8 22.5	SM	Medium dense gray silty SAND (SM), mps 10 mm, no structure, no odor, wet -ALLUVIUM-		5	5	10	40	40				
					204.5 24.8		BOTTOM OF EXPLORATION 24.8 FT										

NOTE: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

Boring No. MW-16

TEST BORING REPORT

HALEY ALDRICH

Boring No. MW-16

Project	BREMO POWER STATION, BREMO BLUFF, VIRGINIA	File No.	41740-000
Client	DOMINION RESOURCE SERVICES, Inc.	Sheet No.	1 of 2
Contractor	FISHBURNE DRILLING	Start	January 29, 2015
		Finish	January 29, 2015
		Driller	J. Rausio
		H&A Rep.	R. Mayer

	Casing	Sampler	Barrel	Drilling Equipment and Procedures
Type	HSA	S	-	Rig Make & Model: CME 55
Inside Diameter (in.)	4 1/4	1 3/8	-	Bit Type: Cutting Head Drill Mud: None
Hammer Weight (lb)	-	140	-	Casing: HSA Spun to
Hammer Fall (in.)	-	30	-	Hoist/Hammer: Cat-Head Safety Hammer PID Make & Model: MiniRAE 2000

Elevation 229.3
Datum NAVD 88
Location See Plan
N 3780772.566
E 11545581

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	USCS Symbol	Well Diagram	Stratum Change Elev/Depth (ft)	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Density/consistency, color, GROUP NAME, max. particle size†, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0							Hand, clear to 4.0 ft, GRAVEL to 1.0 ft										
	3 4	S1 12	4.0 5.0	CH			Medium stiff brown fat CLAY (CH), mps 2 mm, no structure, no odor, moist -FILL-										
5						223.3 6.0											
	2 3 4 4	S2 20	8.0 10.0	CL			Medium stiff gray silty CLAY (CL), mps 10 mm, no structure, no odor, moist to wet, trace roots, and angular quartz fragments		5	5	5	15	70				
10																	
	2 2 7 4	S3 12	13.0 15.0	CL			Similar to S2 except, stiff -ALLUVIUM-										
15						213.3 16.0											
				ML			Medium stiff gray sandy SILT (ML), mps 10 mm, no structure, no odor, wet -ALLUVIUM-			5	15	20	60				
	1 1 2 3	S4 8	18.0 20.0														
20																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth (ft) to: Bottom of Casing	Bottom of Hole	Water
1/29/15	1700	0	0	24.8	18.0
1/30/15	1200	24	24.8	24.8	1.5

Sample ID

O - Open End Rod
T - Thin Wall Tube
U - Undisturbed Sample
S - Split Spoon Sample

Well Diagram

Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary

Overburden (ft) 24.8
Rock Cored (ft) -
Samples 5S

Boring No. MW-16

Field Tests: **Dilatancy**: R - Rapid S - Slow N - None **Plasticity**: N - Nonplastic L - Low M - Medium H - High
Toughness: L - Low M - Medium H - High **Dry Strength**: N - None L - Low M - Medium H - High V - Very High

†Note: Maximum particle size is determined by direct observation within the limitations of sampler size.

Note: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

HALEY ALDRICH

TEST BORING REPORT

Boring No. MW-16
File No. 41740-000
Sheet No. 2 of 2

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	USCS Symbol	Well Diagram	Stratum Change Elev/Depth (ft)	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Density/consistency, color, GROUP NAME, max. particle size†, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
20																	
	3 4 6 7	S5 22	23.0 25.0	SM		206.8 22.5	Medium dense gray silty SAND (SM), mps 10 mm, no structure, no odor, wet -ALLUVIUM-		5	5	10	40	40				
						204.5 24.8	BOTTOM OF EXPLORATION 24.8 FT										

NOTE: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

Boring No. MW-16

OBSERVATION WELL INSTALLATION REPORT

HALEY ALDRICH

Well No.	MW-16
Boring No.	MW-16

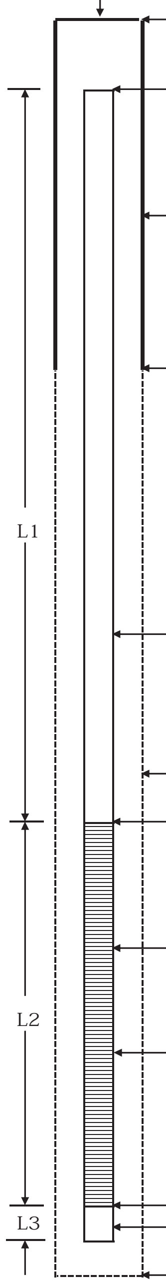
PROJECT	BREMO POWER STATION	**H&A FILE NO.**	41740-001
LOCATION	BREMO BLUFF, VIRGINIA	**PROJECT MGR.**	R. MAYER
CLIENT	DOMINION RESOURCES SERVICES	**FIELD REP.**	R. MAYER
CONTRACTOR	FISHBURNE DRILLING	**DATE INSTALLED**	1/29/2015
DRILLER	J. RAUSIO	**WATER LEVEL**	0.50

Ground El.	229.33 ft	**Location**	3780772.566 N
El. Datum	NAVD 88		11545581.000 E

☑ **Guard Pipe**
☐ **Roadway Box**

SOIL/ROCK CONDITIONS	BOREHOLE BACKFILL
CH -FILL-	CONCRETE
	GROUT
CL, ML -ALLUVIUM-	BENTONITE
	GP #2 SAND
SM -ALLUVIUM-	
24.80	24.80

(Bottom of Exploration)
(Numbers refer to depth from ground surface in feet)



Type of protective cover/lock	Steel	
Height of top of guard pipe/roadway box above ground surface	3.20	ft
Height of top of riser pipe above ground surface	2.98	ft
Type of protective casing:	Steel	
Length	5.0	ft
Inside Diameter	4.0	in
Depth of bottom of guard pipe/roadway box	1.80	ft

Type of Seals	Top of Seal (ft)	Thickness (ft)
Concrete	0.0	1.0
Grout	1.0	10.0
Bentonite Seal	11.0	2.0

Type of riser pipe:	PVC	
Inside diameter of riser pipe	2.0	in
Type of backfill around riser	Bentonite/Grout	
Diameter of borehole	8.25	in
Depth to top of well screen	14.50	ft
Type of screen	PVC	
Screen gauge or size of openings	0.01	in
Diameter of screen	2.0	in
Type of backfill around screen	GP #2 Sand	
Depth of bottom of well screen	24.50	ft
Bottom of Silt trap	24.80	ft
Depth of bottom of borehole	24.80	ft

(Not to Scale)

14.50 ft + 10.0 ft + 0.30 ft = 24.80 ft
Riser Pay Length (L1) + Length of screen (L2) + Length of silt trap (L3) = Pay length

COMMENTS:

Form 2007

HALEY ALDRICH

TEST BORING REPORT

Boring No. MW-17

Project	BREMO POWER STATION, BREMO BLUFF, VIRGINIA
Client	DOMINION RESOURCES SERVICES
Contractor	TERRA SONIC INTERNATIONAL

File No.	41740-001
Sheet No.	1 of 2
Start	March 17, 2015
Finish	March 17, 2015
Driller	G. Sealey
H&A Rep.	R. Mayer
Elevation	239.7
Datum	NAVD 88
Location	N 3780754.94 E 11545686.07

	Casing	Sampler	Barrel
Type			Sonic
Inside Diameter (in.)			6
Hammer Weight (lb)	-		-
Hammer Fall (in.)	-		-

Drilling Equipment and Procedures
- Rig Make & Model: 150 CC Sonic
- Bit Type:
- Drill Mud: None
- Casing: Sonic
- Hoist/Hammer:
- PID Make & Model:

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	USCS Symbol	Well Diagram	Stratum Change Elev/Depth (ft)	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Density/consistency, color, GROUP NAME, max. particle size†, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Dilatancy	Toughness	Plasticity	Strength
0		S1 108	0.0 10.0	GM			Hand clear to 4 ft which sampled as dark gray silty GRAVEL with sand (GM), mps 20mm, no stucture, no odor, moist -FILL-	20	20	5	5	10	40				
				CL		235.2 4.5	Red-brown and dark gray sandy lean CLAY (CL), mps 2 mm, no structure, no odor, moist -FILL-										
5				ML		233.7 6.0	Black and dark gray sandy SILT (ML), mps 2 mm, interbedded laminae 1 to 5 mm thick, no odor, moist to wet -ASH-				10	20	70				
10		S2 96	10.0 20.0	ML			Similar to above except with trace roots										
15				ML			Similar to above										
				CL		221.7 18.0	Gray and tan mottled lean CLAY (CL), mps 3 mm, blocky, no odor, moist -ALLUVIUM-			5	10	15	70				
20																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth (ft) to: Bottom of Casing	Bottom of Hole	Water
3/17/2015	10:00	0	45.59	45.59	35
3/18/2015	10:00	24	45.59	45.59	21

Sample ID
- O - Open End Rod
- T - Thin Wall Tube
- U - Undisturbed Sample
- S - Split Spoon Sample

Well Diagram
- Riser Pipe
- Screen
- Filter Sand
- Cuttings
- Grout
- Concrete
- Bentonite Seal

Summary
- Overburden (ft) 45.59
- Rock Cored (ft) 0
- Samples 5 Sonic

Boring No. MW-17

Field Tests: **Dilatancy**: R - Rapid S - Slow N - None **Plasticity**: N - Nonplastic L - Low M - Medium H - High
Toughness: L - Low M - Medium H - High **Dry Strength**: N - None L - Low M - Medium H - High V - Very High

†**Note: Maximum particle size is determined by direct observation within the limitations of sampler size.**

Note: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

HALEY ALDRICH

TEST BORING REPORT

Boring No. MW-17
File No. 41740-001
Sheet No. 2 of 2

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	USCS Symbol	Well Diagram	Stratum Change Elev/Depth (ft)	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Density/consistency, color, GROUP NAME, max. particle size†, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
20		S3 120	20.0 30.0	CL													
25				CH		214.7 25.0	Red-brown and yellow-brown fat CLAY (CH), mps 2 mm, blocky, no odor, dry -ALLUVIUM										
				CH													
30		S4 120	30.0 40.0	CH			Similar to above										
35				CL		204.7 35.0	Brown red-brown gray (mottled) sandy lean CLAY (CL), mps 5 mm, fine sand partings, no odor, moist to wet -ALLUVIUM-			5	5	15	75				
40		S5 60	40.0 45.5	ML		199.7 40.0	Gray sandy SILT (ML), mps 5 mm, no structure, no odor, wet, micaceous -ALLUVIUM-										
				GP		196.2 43.5	Gray poorly graded GRAVEL with sand (GP), mps 60 mm, no structure, no odor, wet, well rounded river bed gravel -FLUVIAL-	25	50	5	5	10	5				
45						194.1 45.6	BOTTOM OF EXPLORATION 45.59 Boring terminated on top of competent bedrock.										

H&A-TEST BORING-09 REV HA-LIB09-BOS_MAN.GLB HA-TB+CORE+WELL-07-2 W FENCE.GDT O:\41740 BREMO POWER STATION\GINT\001\41740-001BORING_MW17-MW-18.GPJ Mar 27, 15

NOTE: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

OBSERVATION WELL INSTALLATION REPORT

HALEY ALDRICH

Well No.	Boring No.
MW-17	MW-17

PROJECT	BREMO POWER STATION	H&A FILE NO.	41740-001
LOCATION	BREMO BLUFF, VIRGINIA	PROJECT MGR.	R. MAYER
CLIENT	DOMINION RESOURCES SERVICES	FIELD REP.	R. MAYER
CONTRACTOR	TERRA SONIC INTERNATIONAL	DATE INSTALLED	3/17/2015
DRILLER	G. SEALEY	WATER LEVEL	20.66

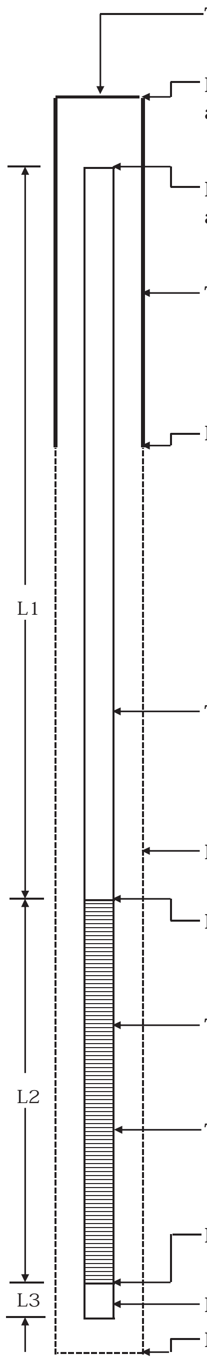
Ground El. 239.73 ft
El. Datum NAVD 88

Location 3780754.94 N
11545686.07 E

☑ Guard Pipe
☐ Roadway Box

SOIL/ROCK CONDITIONS	BOREHOLE BACKFILL
GM -FILL-	CONCRETE
ML -ASH-	GROUT
ML, CL, CH -ALLUVIUM-	BENTONITE
GP -FLUVIAL-	GP #2 SAND
45.59	45.59

(Bottom of Exploration)
(Numbers refer to depth from ground surface in feet)



Type of protective cover/lock	Steel	
Height of top of guard pipe/roadway box above ground surface	3.02	ft
Height of top of riser pipe above ground surface	2.82	ft
Type of protective casing:	Steel	
Length	5.0	ft
Inside Diameter	4.0	in
Depth of bottom of guard pipe/roadway box	1.98	ft

Type of Seals	Top of Seal (ft)	Thickness (ft)
Concrete	0.0	1.0
Grout	1.0	35.5
Bentonite Seal	36.5	2.0

Type of riser pipe:	PVC	
Inside diameter of riser pipe	2.0	in
Type of backfill around riser	Bentonite/Grout	
Diameter of borehole	6.50	in
Depth to top of well screen	40.29	ft
Type of screen	PVC	
Screen gauge or size of openings	0.01	in
Diameter of screen	2.0	in
Type of backfill around screen	GP #2 Sand	
Depth of bottom of well screen	45.29	ft
Bottom of Silt trap	45.59	ft
Depth of bottom of borehole	45.59	ft

(Not to Scale)

Riser Pay Length (L1)		Length of screen (L2)		Length of silt trap (L3)		Pay length
40.29 ft	+	5.0 ft	+	0.30 ft	=	45.59 ft

COMMENTS:

Form 2007

HALEY ALDRICH

TEST BORING REPORT

Boring No. MW-18

Project	BREMO POWER STATION, BREMO BLUFF, VIRGINIA
Client	DOMINION RESOURCES SERVICES
Contractor	TERRA SONIC INTERNATIONAL

File No.	41740-001
Sheet No.	1 of 2
Start	March 17, 2015
Finish	March 17, 2015
Driller	G. Sealey
H&A Rep.	R. Mayer
Elevation	236.3
Datum	NAVD 88
Location	N 3780569.89 E 11546080.64

	Casing	Sampler	Barrel
Type			Sonic
Inside Diameter (in.)			6
Hammer Weight (lb)	-		-
Hammer Fall (in.)	-		-

Drilling Equipment and Procedures

Rig Make & Model: 150 CC Sonic
Bit Type:
Drill Mud: None
Casing: Sonic
Hoist/Hammer:
PID Make & Model:

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	USCS Symbol	Well Diagram	Stratum Change Elev/Depth (ft)	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Density/consistency, color, GROUP NAME, max. particle size†, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
0		S1 72	0.0 10.0	GM			Hand clear to 4 ft which sampled as dark gray silty GRAVEL with sand (GM), mps 15 mm, no structure, no odor, moist -FILL-	20	20	5	5	10	40				
				ML		232.3 4.0	Black and gray sandy SILT (ML), mps 5 mm, interbedded laminae 1 to 5 mm thick, no odor, wet, micaceous -ASH-				10	20	70				
5																	
10		S2 102	10.0 20.0														
15				ML			Similar to above except with trace roots at 16 to 17 feet										
				CL		219.3 17.0	Red-brown and yellow-brown mottled lean CLAY (CL), mps 3 mm, blocky, no odor, moist -ALLUVIUM-			5	10	15	70				
20																	

Water Level Data

Date	Time	Elapsed Time (hr.)	Depth (ft) to: Bottom of Casing	Bottom of Hole	Water
3/17/2015	16:00	0	43.5	43.5	29
3/18/2015	16:00	24	43.5	43.5	19

Sample ID
O - Open End Rod
T - Thin Wall Tube
U - Undisturbed Sample
S - Split Spoon Sample

Well Diagram
Riser Pipe
Screen
Filter Sand
Cuttings
Grout
Concrete
Bentonite Seal

Summary
Overburden (ft) 43.5
Rock Cored (ft) 0
Samples 5 Sonic

Boring No. MW-18

Field Tests: **Dilatancy**: R - Rapid S - Slow N - None **Toughness**: L - Low M - Medium H - High **Plasticity**: N - Nonplastic L - Low M - Medium H - High **Dry Strength**: N - None L - Low M - Medium H - High V - Very High

†**Note: Maximum particle size is determined by direct observation within the limitations of sampler size.**

Note: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

TEST BORING REPORT

Boring No. MW-18
File No. 41740-001
Sheet No. 2 of 2

Depth (ft)	Sampler Blows per 6 in.	Sample No. & Rec. (in.)	Sample Depth (ft)	USCS Symbol	Well Diagram	Stratum Change Elev/Depth (ft)	VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION (Density/consistency, color, GROUP NAME, max. particle size†, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)	Gravel % Coarse	Gravel % Fine	Sand % Coarse	Sand % Medium	Sand % Fine	% Fines	Field Test Dilatancy	Field Test Toughness	Field Test Plasticity	Field Test Strength
20		S3 120	20.0 30.0	CL			Similar to above except with trace roots and wood fragments										
				CH		212.3 24.0	Red-brown and yellow-brown fat CLAY (CH), mps 2 mm, blocky, no odor, dry -ALLUVIUM-				5	10	85				
25																	
				CL		208.3 28.0	Dark gray sandy lean CLAY (CL), mps 5 mm, blocky, no odor, moist, trace roots -ALLUVIUM-		5	5	10	15	65				
30		S4 120	30.0 40.0	CL			Similar to above except wet										
				ML		202.3 34.0	Gray silty SAND (ML), mps 2 mm, no structure, no odor, wet -ALLUVIUM-										
35																	
				CL		199.3 37.0	Brown red-brown gray (mottled) sandy lean CLAY (CL), mps 5 mm, fine sand partings, no odor, moist -ALLUVIUM			5	5	15	75				
				ML		197.3 39.0	Gray sandy SILT (ML), mps 5 mm, no structure, no odor, wet, micaceous -ALLUVIUM-										
40		S5 39	40.0 43.5														
				GP		194.3 42.0	Gray poorly graded GRAVEL with sand (GP), mps 60 mm, no structure, no odor, wet, well rounded river bed gravel -FLUVIAL-	25	50	5	5	10	5				
						192.8 43.5	BOTTOM OF EXPLORATION 43.5 FT Boring terminated on top of competent bedrock.										

NOTE: Soil identification based on visual-manual methods of the USCS as practiced by Haley & Aldrich, Inc.

HALEY ALDRICH

OBSERVATION WELL INSTALLATION REPORT

Well No. **MW-18**
Boring No. **MW-18**

PROJECT	BREMO POWER STATION	**H&A FILE NO.**	41740-001
LOCATION	BREMO BLUFF, VIRGINIA	**PROJECT MGR.**	R. MAYER
CLIENT	DOMINION RESOURCES SERVICES	**FIELD REP.**	R. MAYER
CONTRACTOR	TERRA SONIC INTERNATIONAL	**DATE INSTALLED**	3/17/2015
DRILLER	G. SEALEY	**WATER LEVEL**	18.92

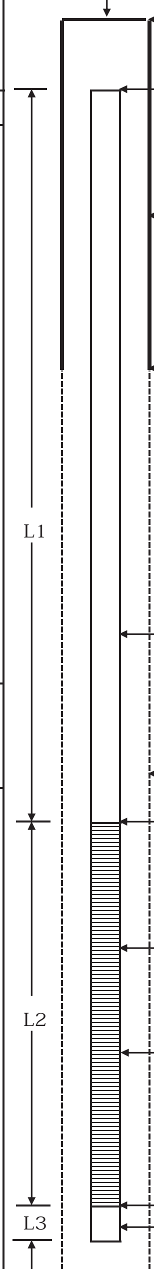
Ground El. 236.31 ft
El. Datum NAVD 88

Location 3780569.89 N
11546080.64 E

☑ Guard Pipe
☐ Roadway Box

SOIL/ROCK CONDITIONS	BOREHOLE BACKFILL
GM -FILL-	CONCRETE
ML -ASH-	GROUT
ML, CL, CH -ALLUVIUM-	BENTONITE
GP -FLUVIAL-	GP #2 SAND
43.50	43.50

(Bottom of Exploration)
(Numbers refer to depth from ground surface in feet)



(Not to Scale)

Type of protective cover/lock	Steel	
Height of top of guard pipe/roadway box above ground surface	3.05	ft
Height of top of riser pipe above ground surface	2.91	ft
Type of protective casing:	Steel	
Length	5.0	ft
Inside Diameter	4.0	in
Depth of bottom of guard pipe/roadway box	1.95	ft

Type of Seals	Top of Seal (ft)	Thickness (ft)
Concrete	0.0	1.0
Grout	1.0	32.0
Bentonite Seal	33.0	3.2

Type of riser pipe:	PVC	
Inside diameter of riser pipe	2.0	in
Type of backfill around riser	Bentonite/Grout	
Diameter of borehole	6.50	in
Depth to top of well screen	38.20	ft
Type of screen	PVC	
Screen gauge or size of openings	0.01	in
Diameter of screen	2.0	in
Type of backfill around screen	GP #2 Sand	
Depth of bottom of well screen	43.20	ft
Bottom of Silt trap	43.50	ft
Depth of bottom of borehole	43.50	ft

38.20 ft + 5.0 ft + 0.30 ft = 43.50 ft

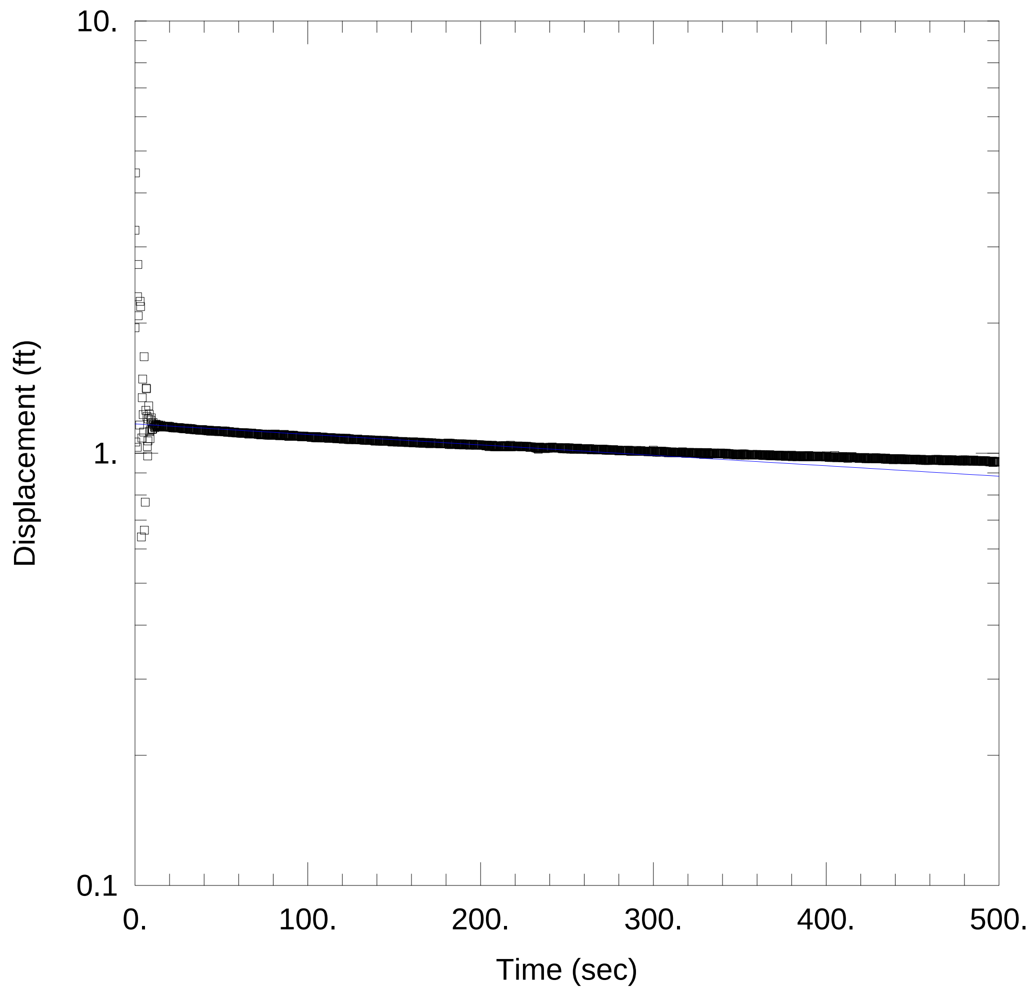
Riser Pay Length (L1) + Length of screen (L2) + Length of silt trap (L3) = Pay length

COMMENTS:

Form 2007

APPENDIX B

AQUIFER SLUG TEST RESULTS



WELL TEST ANALYSIS

Data Set: L:\...\MW-3 (Falling).aqt
Date: 04/09/13 Time: 16:41:12

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-3 (Falling)
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.5

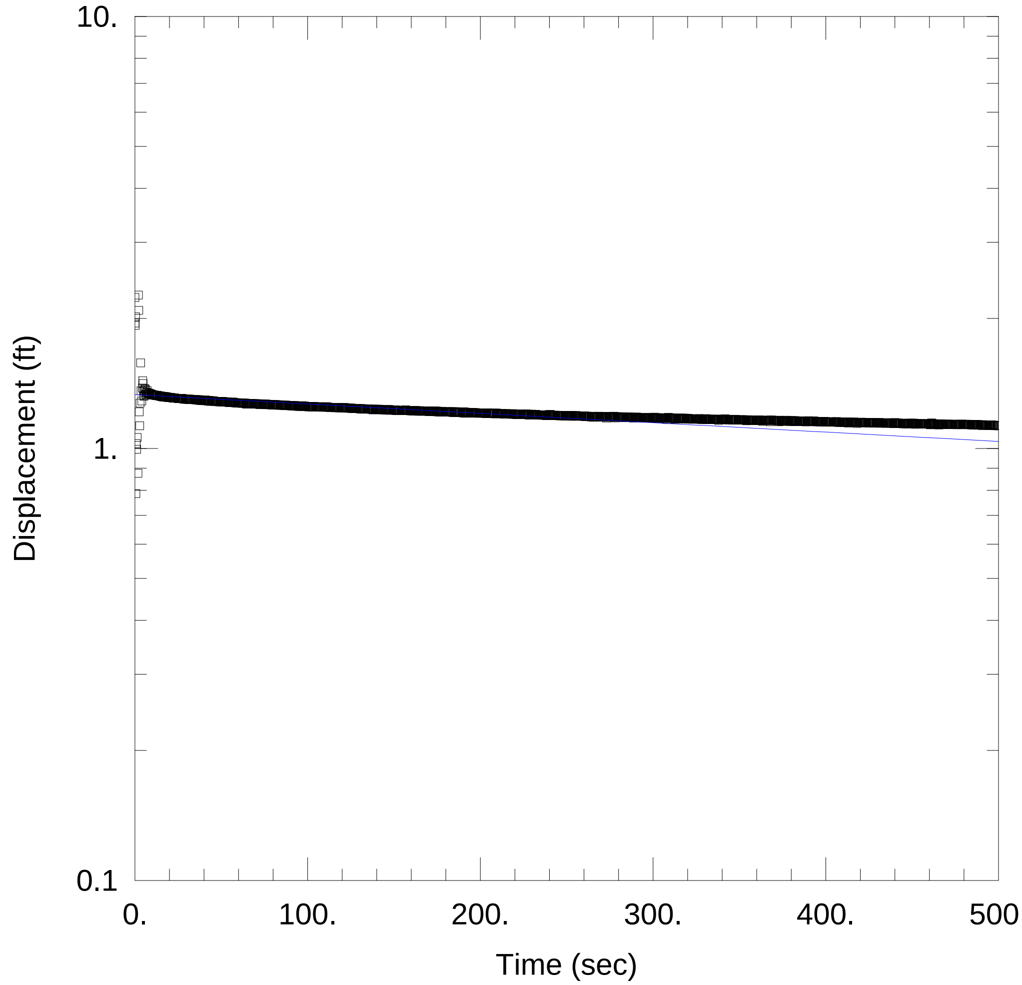
WELL DATA (MW-3 (Falling))

Initial Displacement: 1.95 ft
Total Well Penetration Depth: 20. ft
Casing Radius: 0.08 ft
Static Water Column Height: 15.21 ft
Screen Length: 10. ft
Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.05916 ft/day
y0 = 1.168 ft



WELL TEST ANALYSIS

Data Set: L:\...\MW-3 (Rising).aqt
Date: 04/09/13 Time: 16:42:39

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-3 (Rising)
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.5

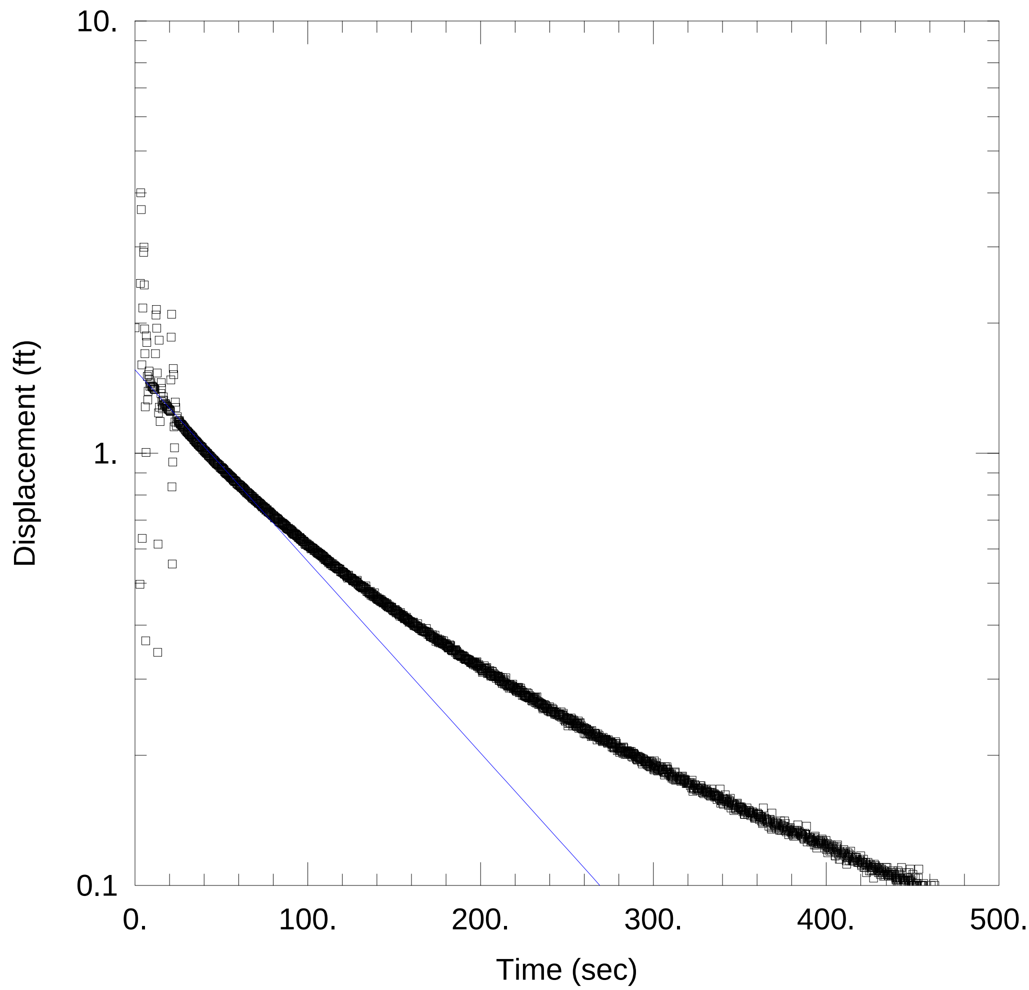
WELL DATA (MW-3 (Rising))

Initial Displacement: 1.95 ft
Static Water Column Height: 15.21 ft
Total Well Penetration Depth: 20. ft
Screen Length: 10. ft
Casing Radius: 0.08 ft
Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.05301 ft/day
y0 = 1.332 ft



WELL TEST ANALYSIS

Data Set: L:\...\MW-5(falling).aqt
Date: 04/09/13 Time: 16:43:20

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-7
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.5

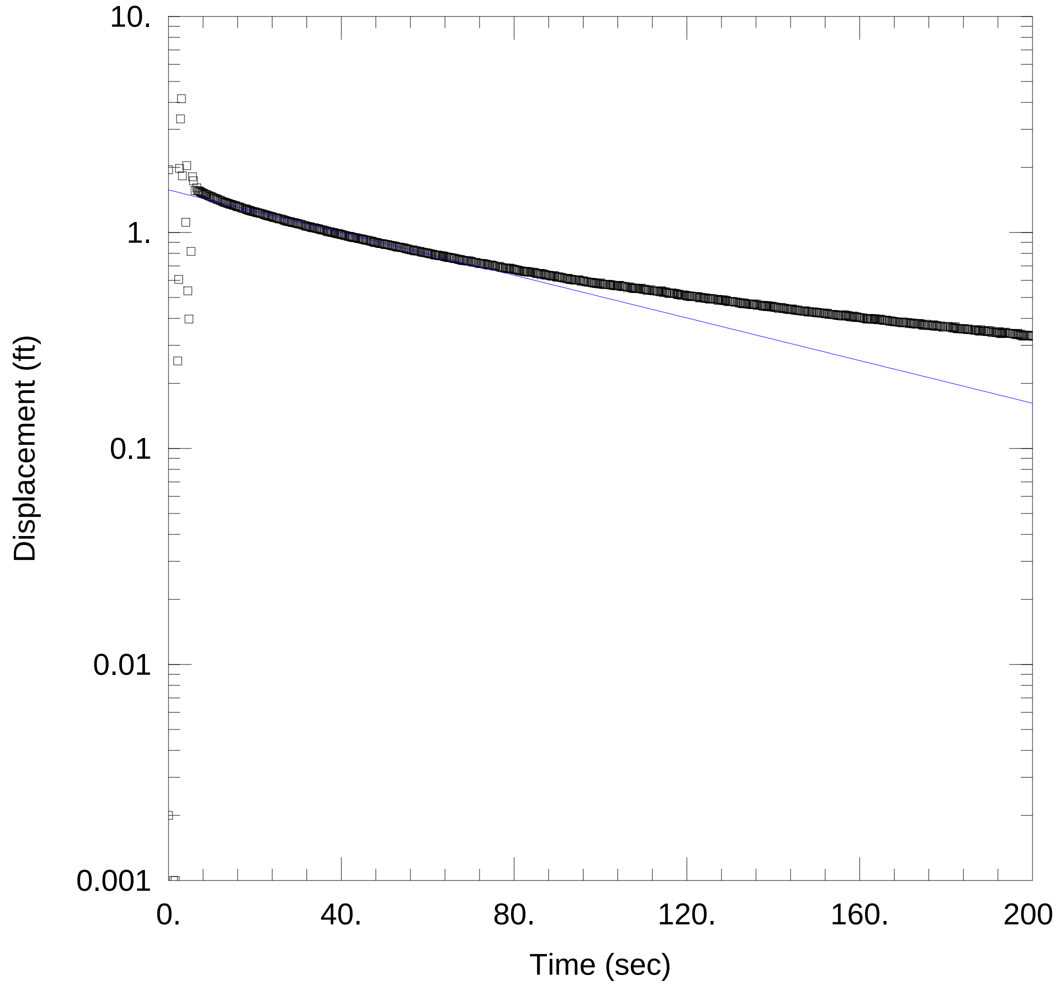
WELL DATA (MW-5)

Initial Displacement: 1.95 ft
Total Well Penetration Depth: 20. ft
Casing Radius: 0.08 ft
Static Water Column Height: 18.63 ft
Screen Length: 10. ft
Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.085 ft/day
y0 = 1.559 ft



WELL TEST ANALYSIS

Data Set: L:\...\MW-5(Rising).aqt
Date: 04/09/13 Time: 16:43:46

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-7
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.5

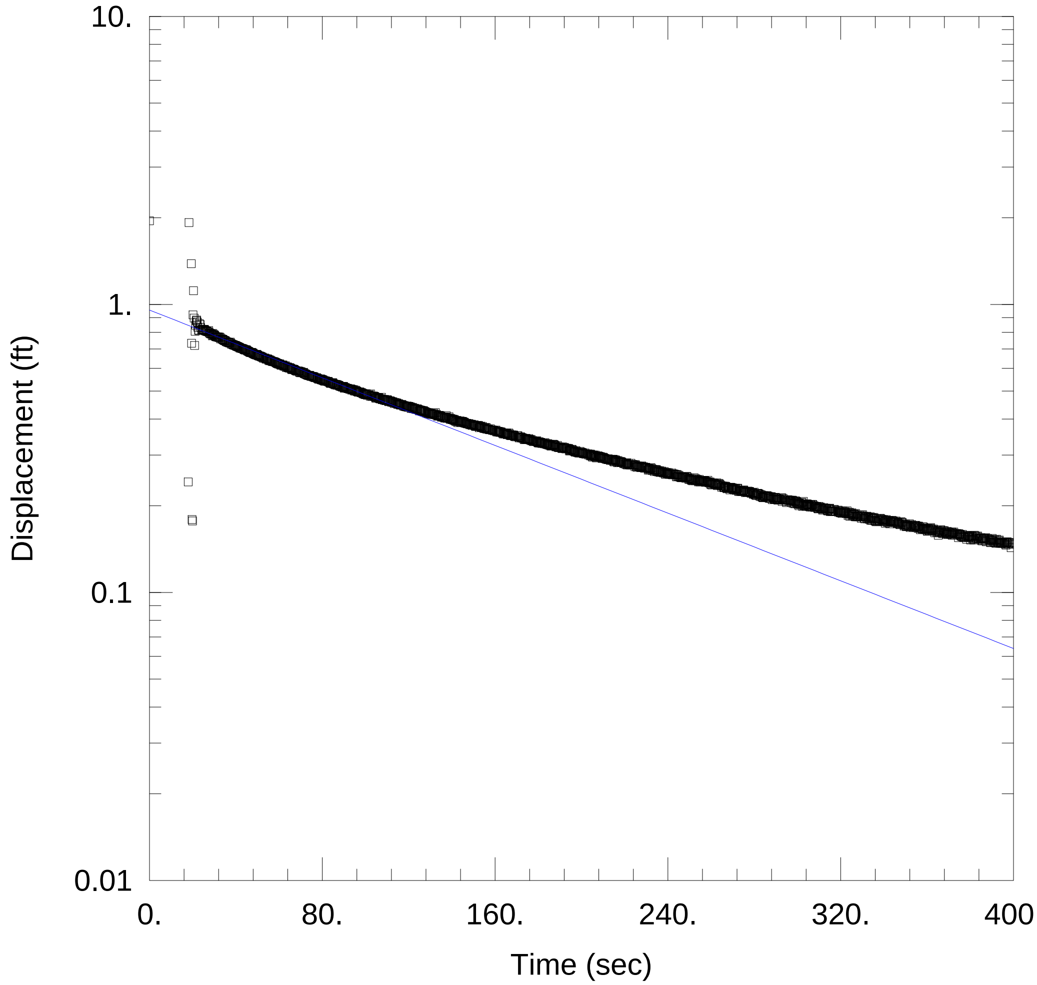
WELL DATA (MW-5)

Initial Displacement: 1.95 ft
Total Well Penetration Depth: 20. ft
Casing Radius: 0.08 ft
Static Water Column Height: 18.63 ft
Screen Length: 10. ft
Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.208 ft/day
y0 = 1.573 ft



WELL TEST ANALYSIS

Data Set: L:\...\MW-7(falling).aqt
Date: 04/09/13 | Time: 16:44:16

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-7
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft | Anisotropy Ratio (Kz/Kr): 0.5

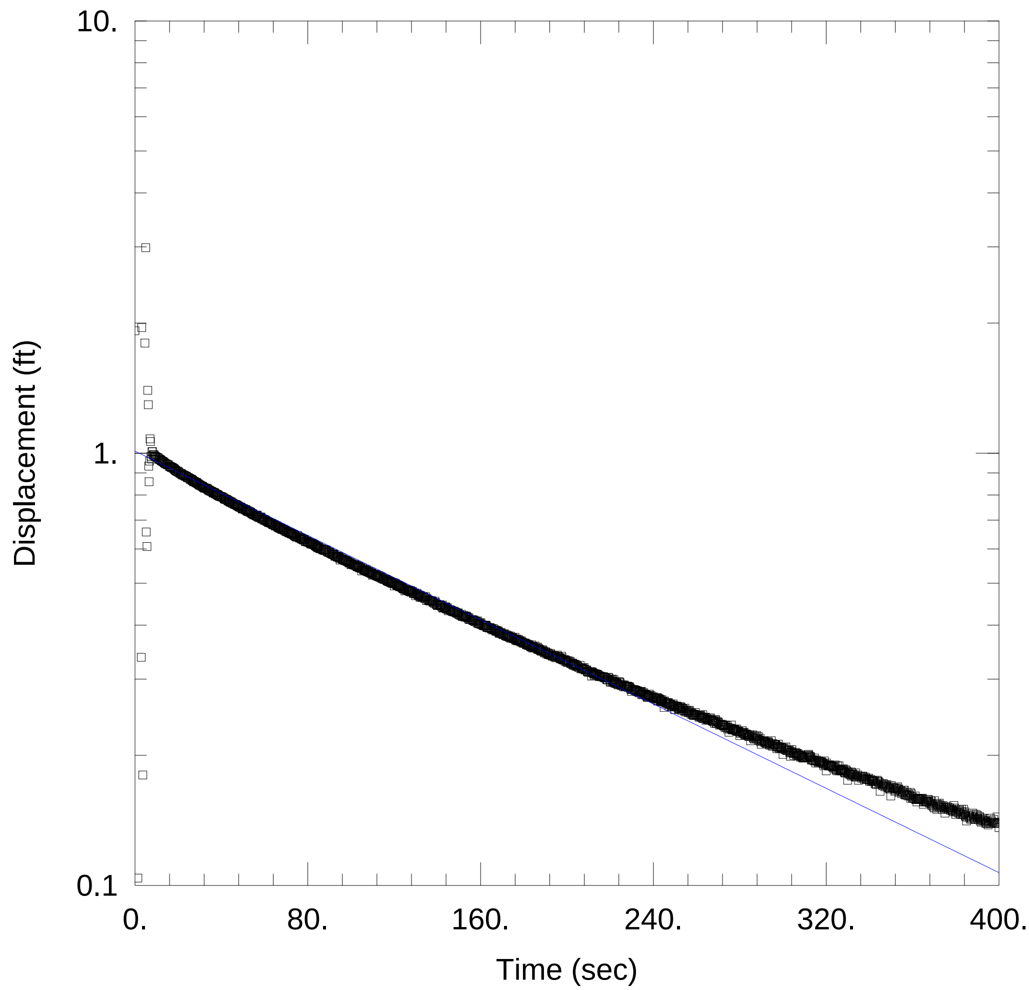
WELL DATA (MW-7)

Initial Displacement: 1.95 ft | Static Water Column Height: 16.84 ft
Total Well Penetration Depth: 20. ft | Screen Length: 10. ft
Casing Radius: 0.08 ft | Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined | Solution Method: Bouwer-Rice

K = 0.7186 ft/day | y0 = 0.9557 ft



WELL TEST ANALYSIS

Data Set: L:\...\MW-7(Rising).aqt
Date: 04/09/13 Time: 16:44:38

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-7
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft Anisotropy Ratio (Kz/Kr): 0.5

WELL DATA (MW-7)

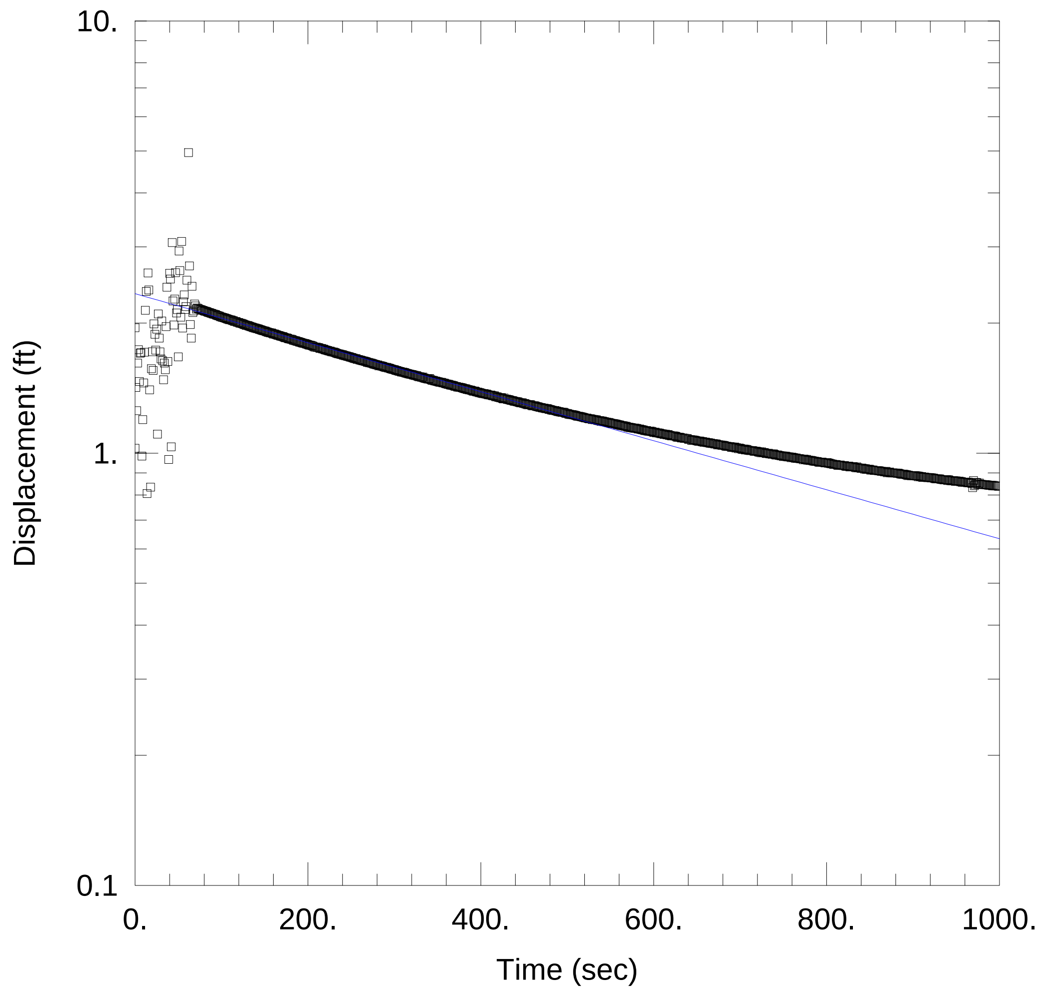
Initial Displacement: 1.92 ft
Total Well Penetration Depth: 20. ft
Casing Radius: 0.08 ft

Static Water Column Height: 15.41 ft
Screen Length: 10. ft
Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.5964 ft/day y0 = 1.011 ft



WELL TEST ANALYSIS

Data Set: L:\...\MW-11 (Falling).aqt
Date: 04/09/13 Time: 16:47:02

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-7
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft Anisotropy Ratio (Kz/Kr): 0.5

WELL DATA (MW-11)

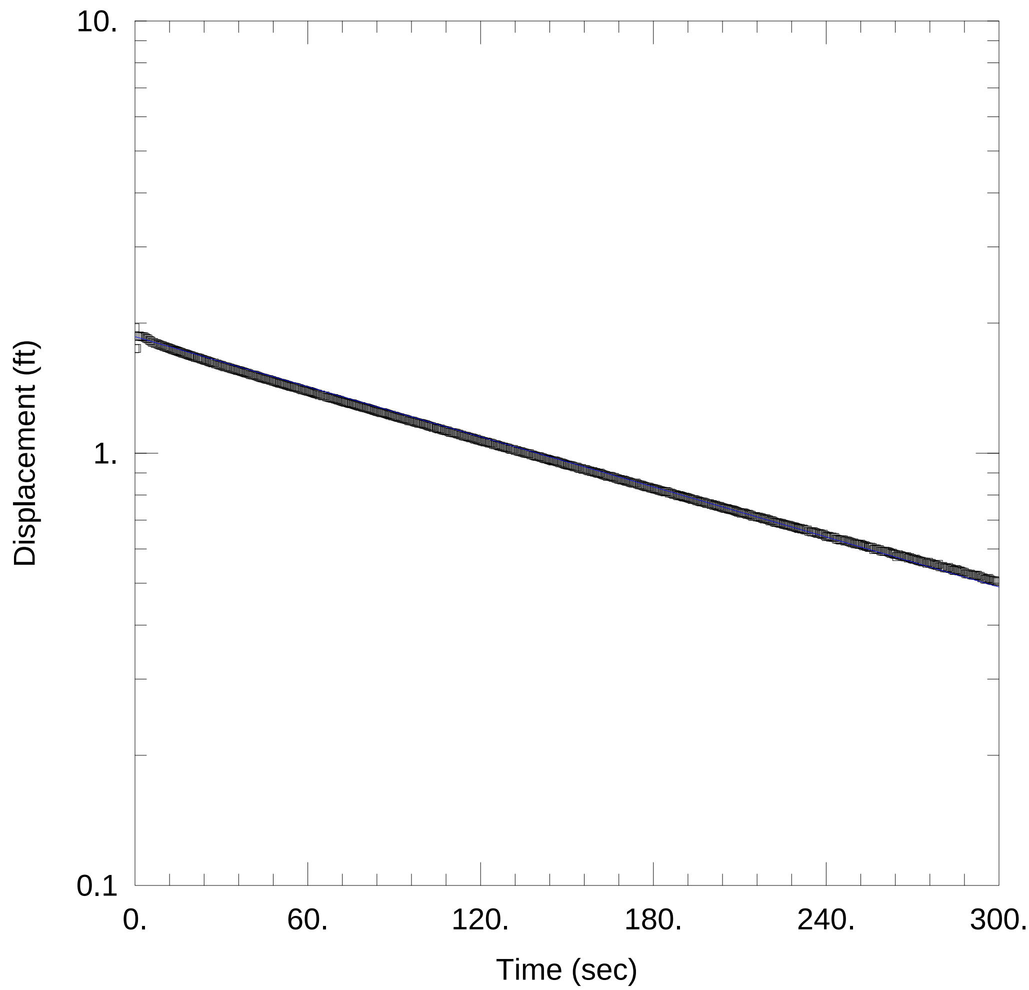
Initial Displacement: 1.95 ft
Total Well Penetration Depth: 44. ft
Casing Radius: 0.08 ft

Static Water Column Height: 13.04 ft
Screen Length: 10. ft
Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.1519 ft/day y0 = 2.339 ft



WELL TEST ANALYSIS

Data Set: L:\...\MW-11 (Rising).aqt
Date: 04/09/13 Time: 16:45:34

PROJECT INFORMATION

Company: GES
Client: Dominion-Bremo Bluff
Project: 1201882
Location: Bremo Bluff, VA
Test Well: MW-11 (Rising)
Test Date: 2-28-13

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.5

WELL DATA (MW-11)

Initial Displacement: 1.95 ft
Static Water Column Height: 13.04 ft
Total Well Penetration Depth: 44. ft
Screen Length: 10. ft
Casing Radius: 0.08 ft
Well Radius: 0.08 ft
Gravel Pack Porosity: 0.28

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.5171 ft/day
y0 = 1.86 ft

APPENDIX C

GROUNDWATER MONITORING WELL CONSTRUCTION SPECIFICATIONS
WELL DEVELOPMENT GUIDANCE
WELL DECOMMISSIONING GUIDANCE

1.0 DRILLING

1.1 Nominal Boring Diameter

In all cases where the diameter of the well pipe will be 2 inches, the minimum nominal borehole diameter of borings advanced through soil materials will be 6 inches in order to help ensure that the minimum width of the annulus around the well pipe will be 2 inches.

1.2 Drilling Methods

All borings will initially be advanced by air-rotary drilling methods.

1.3 Cuttings

Drilling will be performed in a manner that minimizes the spreading of soil cuttings. Disposition of cuttings upon project completion will be the responsibility of Owner/Operator or the Owner/Operator's designated representative. Cuttings will be disposed of in accordance with the DEQ's Investigative Derived Waste Disposal Policy.

2.0 SOIL SAMPLING

2.1 Cuttings

During air-rotary drilling, the driller will attempt to sample soil by providing cuttings at intervals specified by the Owner/Operator or the Owner/Operator's representative. The driller will keep cuttings clear of the borehole.

2.2 Discrete Soil Samples

When using hollow stem auger or other drilling methods designed to facilitate the collection of discrete samples, the driller should attempt to collect samples on a minimum 5-foot interval for logging, unless otherwise instructed by the Owner/Operator or the Owner/Operator's representative.

2.3 Sample Disposition

Disposition of sample material upon completion of the project will be the responsibility of the Owner/Operator or the Owner/Operator's designated representative.

3.0 WELL CONSTRUCTION

3.1 Well Pipe and Screen

Each monitoring well will be constructed of pre-cleaned Schedule 40 PVC pipe having an inner diameter of 2 inches.

The base of each well will terminate with a screen 10 feet in length. Screens will be factory-slotted. Slots will be 0.01 inch in width.

The driller will wear clean surgical-type gloves whenever handling PVC well pipe, and the pipe will be maintained in a clean manner.

In order to provide a clean cut, a PVC pipe cutter will be used whenever it is necessary to shorten sections of the PVC well pipe; a hacksaw will not be used.

3.2 Sand Pack

Filter sand will be a clean sand of proper size in relation to the screen slots to prevent its passage into the well, with no fraction coarser than 0.25-inch nominal diameter.

Filter sand will be placed in the annulus around the well riser and to a point approximately two feet above the top of the screen. A tremie pipe will be used as feasible.

3.3 Bentonite Seal

The annulus around the well pipe will be sealed with a layer of bentonite pellets, to be placed directly above the sand filter pack. The minimum thickness of the bentonite layer will be approximately two feet. The bentonite pellets will be allowed a minimum time of 24 hours for hydration prior to continuing with well construction. A tremie pipe will be used as feasible

3.4 Grout

Following hydration of the bentonite seal, each boring will be sealed with a Portland Type I bentonite/cement slurry, using the tremie pipe method.

Bentonite content in the slurry will be 2 to 5 percent by weight to help reduce shrinkage.

3.5 Surface Completion

The driller will be prepared for either manhole or stickup surface completions.

In the case of manhole installations, suitable surface completion will consist of capped PVC riser and steel manhole.

The PVC riser will be provided with a lockable, watertight, expansion cap. The driller will provide a lock for each cap. All locks will be keyed identically and all keys relinquished to the owner.

The manhole will be placed in a manner that permits surface water to runoff and drain away from the manhole cover.

In the case of stickup installations, suitable surface completion will consist of a concrete apron, capped PVC well riser, and outer protective casing. The apron will be constructed in such a manner that surface water will not return to it.

The concrete apron will have the following minimum dimensions: 4 feet x 4 feet x 3.5 inches, and will be centered with respects to the riser. A form will be used in constructing the apron. The form will be centered with respect to the PVC riser. The upper surface of the apron will be graded to provide drainage away from the PVC riser. A spike will be set into the pad for surveying purposes.

The inner PVC riser (well pipe) will extend to an approximate height of 1.75 feet above the top of the concrete pad. A vent hole having a diameter of 0.25 inches will be drilled through the PVC riser at a point 2 inches below its top. Shavings generated by drilling the PVC riser will be prevented from falling into the well. The PVC riser will be provided with a slip on PVC cap.

The outer protective casing will be constructed of steel pipe having a diameter, or diagonal, of not less than 8 inches. The top of the outer protective casing, when uncovered, will be placed at a point between 0.5-inch above the top of the PVC well pipe and 0.5-inch below the top of the PVC pipe. A drain hole having a diameter of 0.5-inch will be drilled through the outer protective casing near the top of the concrete apron. Shavings generated by drilling the steel casing will be prevented from falling into the well. The casing will be marked for surveying purposes.

The outer protective casing will be lockable. The driller will provide a lock for each protective casing cap. All locks will be keyed identically.

4.0 SURVEYING

A licensed surveyor will survey well elevation. Survey point(s) will include:

- concrete pad (marked with a spike);
- outer protective steel casing, when open (engraved mark);
- inner PVC well pipe (engraved mark);
- ground surface (not marked);
- well location to within ± 0.5 foot in horizontal plane;
- ground surface elevation to within ± 0.01 foot;
- surveyor's pin elevation on concrete apron within ± 0.01 foot;
- top of monitoring well casing elevation to within ± 0.01 foot; and,
- top of protective steel casing elevation to within ± 0.01 foot.

5.0 WELL DEVELOPMENT AND INSPECTION

The driller will develop each well until sediment free water with stabilized field constituents (i.e., temperature, pH and specific conductance) is obtained.

Development will be conducted using a surge block followed by pumping or bailing. The surge block may be used as a means of assessing the integrity of the well screen and riser.

In the event a pump is employed, the design of the pump will be such that any groundwater that has come into contact with air is not allowed to drain back into the well. Air surging will not be used.

All well development equipment (bailers, pumps, surge blocks) and any additional equipment that contacts subsurface formations will be decontaminated prior to on site use, between consecutive on site uses, and/or between consecutive well installations, as directed by Owner/Operator or Owner/Operator's designated representative.

6.0 ANCILLARY REQUIREMENTS

6.1 Extraneous Material

The driller will take all reasonable care to ensure that each boring is free from all materials other than those required for well construction. Materials required for well construction is here defined to include polyvinyl chloride (PVC), sand, bentonite, Portland cement and natural soil materials. All other materials accidentally or purposely placed in the hole will be removed by driller prior to well completion.

6.2 Decontamination

All drilling equipment (drill steel, bits, casing materials) and any additional equipment, that contacts subsurface formations will be decontaminated prior to on site use, between consecutive on site uses, and/or between consecutive well installations, as directed by Owner/Operator or Owner/Operator's designated representative.

Appropriate decontamination procedure will consist of steam cleaning with potable water and biodegradable detergent (e.g., Liquinox) approved by Owner/Operator or Owner/Operator's designated representative. Steam cleaning will be conducted in a manner that minimizes over-spray and runoff.

6.3 Disposition of Waste Water

If drilling fluids are used or monitoring wells constructed in an area of suspected contamination, well development wastewater will be placed in 55-gallon drums at the well site and subsequently transported to a publicly operated treatment works (POTW) or the sites leachate collection system for disposal.

6.4 Site Safety Plan

The driller is responsible for maintaining the personal safety of his employees while on site. The driller will keep a fire extinguisher (in good working condition) and first aid kit at the site at all times during which his employees occupy the site.

The driller will be responsible for providing any personal protective equipment that might be required by state and federal occupational safety and health agencies, including, but not necessarily limited to, hard hats, hearing protection and steel-toed boots, for all personnel employed by the driller.

6.5 Cleanup

The driller will be responsible for removing all refuse from each well site. Such refuse typically includes, but is not limited to, PVC pipe wrappers, sand bags, bentonite bags, cement bags, beverage containers, food wrappers and other forms of litter. Smoking on site will not be permitted.

The driller will be responsible for providing the following information to the Owner/Operator's designated representative after well installation has been performed:

- date and time of construction;

- drilling method and fluid used (if applicable);
- boring diameter;
- well pipe (inner casing) specifications;
- well depth (+/-0.01 ft.);
- drilling/lithologic logs;
- specifications for other casing materials (if applicable);
- screen specifications;
- well pipe/screen joint type;
- filter pack specifications (material, size);
- filter pack volume and calculations;
- filter pack placement methods;
- bentonite seal specifications;
- bentonite seal volume;
- bentonite seal placement method;
- grout specifications;
- grout volume;
- grout placement method;
- surface completion specifications;
- well development procedure;
- type of protective well cap; and
- as-built well diagram including dimensions.

7.0 WELL CONSTRUCTION AND SOIL BORING LOGS

In accordance with 9VAC-20-81-250.A of the Virginia Solid Waste Management Regulations, copies of well construction and soil boring logs will be forwarded to the DEQ following completion of well construction activities.

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WELL DEVELOPMENT PROCEDURES

- Record the static water level in the well.
- If a pump is present in the well, remove the pump from the well and measure the total depth of the well.
- Calculate saturated volume of the well and filter pack.
- Using a disposable bailer, collect a water sample from the top of the water column and record field measurements of water quality parameters (Water Quality Parameters (WQP): turbidity, pH, temperature, and specific conductance).
- Surge the well with the teflon surge block or large diameter weighted bailer for three to five minutes.
- Remove the surging device and purge the well with a pneumatic well development pump at a rate that is greater than the natural recharge rate of the well.
- Containerize all purge water for disposal at the location designated by the site.
- Record measurements of WQP on development logs following the removal of each consecutive well and filter pack volume.
- Continue purging until the turbidity level stabilizes or is reduced to less than 5 NTU, then repeat surging with surge block. Surging and purging are to be continued for a minimum of 4 hours, or until turbidity levels following a surging event are less than 10 NTU.
- If the well purges dry, record the rate of recharge and continue purging and surging activities after the well has recovered. Reduce the purge rate to slightly less than the natural recharge rate of the well.
- All non-disposable equipment that will be placed inside of the well during the development process will be decontaminated prior to each day's use using a phosphate-free detergent followed by a deionized water rinse.
- Purge water should be disposed of in a manner that is consistent with the Virginia Department of Environmental Quality's Investigative Derived Waste Disposal Policy.

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WELL DECOMMISSIONING PROCEDURES

1.0 STANDARD OVERVIEW

This Standard represents recommended procedures for decommissioning monitoring wells at solid waste facilities. All wells (monitor wells, water supply wells, etc.) and piezometers not actively being used for their intended purpose and with no future plan for utilization should be decommissioned. Wells and piezometers represent potential conduits for cross-contamination through annulus transfer, improper construction, corrosion, accidents and vandalism. Proper decommissioning eliminates the potential for cross-contamination. In addition to the threat of cross-contamination, improperly decommissioned wells can pose a threat to the integrity of future baseliners. In expansion areas over unconsolidated material, unless the well casing is removed and replaced with a flexible grout, the casing can damage the baseliner in the event of differential settlement or subsidence. The weight of the overlying waste mass often causes a limited amount of subsidence, especially in fine-grained deposits. Since future expansions can occur in areas not currently foreseen, all unused wells within the vicinity of a solid waste disposal facility should be abandoned in accordance with this Standard.

The following well decommissioning procedures are designed to ensure that well materials (including cement grout) will not cause damage to liner materials in the event of subsidence and to minimize the potential for contaminant migration through annular materials. Where regulatory requirements conflict with the procedures described herein, approval should be sought to adhere to this Standard. The procedures described in this Standard generally meet or exceed most regulatory requirements. Possible reasons for variation to this Standard include, but are not limited to, unusual site hydrogeologic conditions, deep wells (>100 feet), multiple cased monitor wells or larger diameter wells (>4"), driven casing wells and State-specific well decommissioning requirements that differ from this Standard.

The goal of well decommissioning is to remove <u>all</u> borehole components including the existing grout and gravel pack and replace the borehole contents with a suitable grout mixture. Removal of all borehole components is best accomplished by overdrilling the well using an auger of a diameter 1.25 times that of the original borehole coupled with a centering device.

This standard was developed in consideration of the following reference materials:

- ASTM D 5299-99, 2005. Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities. ASTM 1993 Annual Book of Standards, vol. 04.08, pp. 1318-1333.
- AWWA/ANSI A100-06, 2006. AWWA Standard for Water Wells, American Water Works Association, Denver Colorado. Appendix G.
- Lutenegger, A.J. and DeGroot, D.J. 1993, Hydrologic properties of contaminant transport barriers as borehole sealants. Hydraulic conductivity and Waste Contaminant Transport in Soils, ASTM STP 1142, D.E. Daniel and S.J. Trautwein, eds., ASTM Philadelphia, Pennsylvania.
- NWWA, 1975 (National Water Well Association Committee on Water Well Standards, 1975) Manual of Water Well Construction Practices, EPA –570/9-75-001. Office of Water Supply, Washington D.C.
- Smith, S.A., 1994, Well & Borehole Sealing, S.A. Smith Consulting Services, Ada, Ohio with Wisconsin Water Well Association for Groundwater publishing Co., Dublin, Ohio, 69p.

2.0 SURVEY CONTROL

Unless detailed survey information exists, each well shall be surveyed for both horizontal and vertical control, prior to decommissioning. The location of the well shall be surveyed to the nearest 0.5 feet. The ground surface elevation and top of well casing shall also be surveyed to the nearest 0.1 feet and 0.1 feet, respectively, relative to mean sea level. A State-licensed surveyor shall perform surveying.

3.0 GROUT SPECIFICATIONS

The following are specifications for three grout mixtures commonly used in well decommissioning and referenced throughout this Standard:

1. <u>Neat cement grout</u> - a mixture in the proportion of 94 pounds of Portland cement and not more than six gallons of water. Used to decommission wells completed in competent bedrock formations.

2. <u>Neat Bentonite grout</u> - a mixture in the proportion of 94 pounds of Portland cement and not more than six gallons of water, with bentonite up to five percent by weight of cement (between 3 and 4.7 pounds of bentonite per 94 pounds of Portland cement). Used to decommission wells completed in competent bedrock formations.

3. <u>High solids bentonite grout</u> - a mixture of water and a minimum of 30 percent by weight of bentonite (see discussion below), with no additives (minimum of 2.5 pounds of bentonite per gallon of water). Used to decommission wells completed in unconsolidated materials and competent rock, where appropriate.

Typically, a high solids grout can be prepared using granular bentonite and pumped at a relatively low-viscosity state if done quickly (within 15 minutes). This is due to the slower hydration of the granular bentonite as compared to powdered bentonite. However, if these timeframes cannot be achieved or if it is desirable to have a slower "set," an alternative is to use what has been termed the "Ohio mix". The "Ohio mix" involves preparing a low-solids bentonite grout slurry (30 to 50lbs/100 gallons of water) using API 200-mesh bentonite (e.g., Natural Gel, Gold Seal), into which 125 lb. of granular bentonite (8 to 20-mesh) is added and mixed (stirred). The hydrated bentonite in the slurry delays hydration of the granular bentonite without the addition of polymers or other agents. The result is a high solids bentonite grout at a viscosity that is feasible to pump with reasonable working time (Eidil et al. 1992 from Smith, 1994).

3.1 Cement

The cement shall be Portland Cement® Type 1 in accordance with ASTM C150, Type 1 or API-10A, Class A.

3.2 Water

Water shall be obtained from an approved source. Water used for down-hole purposes shall have a Total Dissolved Solids (TDS) concentration of less than 500 mg/L (Smith, 1994) and be certified free from contaminants, or sampled for volatile organic compounds by EPA method 8260.

3.3 Bentonite

Bentonite shall be an <u>additive free</u> granular sodium bentonite (Benseal, Enviroplug, PDS Granular, Volclay Crumbles or equivalent) generally 8 to 20 mesh particle size. Use of granular bentonite *in lieu* of powdered bentonite allows the placement of a high-solids grout with relatively low viscosity, if mixing and pumping are done quickly. If following the "Ohio mix" discussed above, additive free API 200-mesh bentonite is used for the initial slurry (e.g., Natural Gel, Gold Seal) into which granular bentonite (8 to 20 mesh) is added and mixed.

3.4 Grouting Equipment

Grout mixers shall be paddle or blade type capable of thoroughly mixing grout. All grouting lines (i.e., hoses, pipes, drill rods, etc.) shall have an inside diameter of at least 0.50 inches to prevent clogging. Grout pumps shall be of a positive displacement or progressive cavity type (Moyno) capable of delivering a minimum pressure of 20 psi. Venturi mixing and centrifugal pumps are less desirable alternatives due to clay particle shearing and clogging problems, respectively.

4.0 DECOMMISSIONING PROCEDURES

Decommissioning procedures must be tailored to each well type and geologic environment. The broad range of suitable decommissioning methods for different situations is covered in detail in ASTM D5299-99 and the above referenced standards and literature. The purpose of this standard is to establish minimum requirements for the most common well construction types at our facilities. For landfill facilities, the most common type of well installation consists of single cased wells installed in unconsolidated material at relatively shallow depths (i.e., < 100 feet). The procedures described herein can be used to decommission two-inch or four-inch diameter single cased PVC or steel wells installed at depths generally less than 100 feet. Other less common well types requiring specialized procedures and materials include large diameter wells, multiple cased wells and driven casing wells.

The goal of decommissioning is to completely remove all well materials either through overdrilling or pulling of the well or casing. Once all well materials have been removed, the resulting borehole can be properly sealed with a suitable grout mixture.

In general, a high solids bentonite grout mixture (30% by weight) is preferred for most well decommissioning projects. State regulations often stipulate that for wells installed in bedrock, non-flexible grout mixtures must be used, such as neat cement grout or neat bentonite grout. Non-flexible grout mixtures more closely match the physical characteristics of competent bedrock. For all wells or portions of wells completed in unconsolidated material a high solids bentonite grout as defined above is the requisite grouting material. For wells of portions of wells completed in competent bedrock grouting materials can be either of the three grout types specified above with preference given to high solids bentonite grout.

The following are specific decommissioning procedures. These steps shall generally be completed in the order listed below.

1. Ensure that adequate survey control exists for each well and obtain a copy of the original well construction log.
2. Well decommissioning drilling equipment, augers, water level marker, and other tools must be decontaminated before being brought to the site.
3. The depth of the well shall be measured and compared to the anticipated well depth to determine if any obstructions are in the well. If the well is obstructed, the obstruction will be removed prior to sealing the well, if possible.
4. Expected grout volume calculations shall be completed using the depth information derived from Steps 1 and 3. The expected volume shall be recorded for reconciliation with the final grout volumes used.
5. Remove the protective casing. Position the drill rig directly over the well and attach a chain to the outer protective casing. Pull directly upward on the protective casing. Often for shallow wells this procedure will also pull up the inner-casing and annular materials. If this occurs, continue to pull all well materials out, as practicable.

6. Remove the well casing and associated annular materials. Typically, removal is accomplished through overdrilling using a Hollow Stem Auger (HSA) drill rig equipped with an auger bit that exceeds the diameter of the original bit (1.25 times the original auger diameter) used to construct the well. The key to successful overdrilling is insuring the auger bit remains centered on the well for the duration of overdrilling. For wells constructed of PVC, either employ a pilot bit to insure centering is maintained or place A-rod (steel rod) throughout the length of the well to act as a guide during overdrilling. A pilot bit consists of an elongate pointed pin with a maximum diameter slightly less than that of the inner well casing. For wells constructed of steel materials, the steel casing itself can be used to maintain centering during overdrilling. Essentially, an auger is selected with an inner diameter slightly larger than the diameter of the steel casing. During overdrilling the auger follows the steel casing to the target depth. Centering must be assured through use of one of the above-described centering methods. The overdrilling shall progress slowly to insure that the drilling operation remains centered over the well/boring. Once the base of the well is reached the auger or drilling equipment shall be left in place, to prevent cave in of materials, while proceeding to Step 6.

   <u>For unconsolidated wells installed using driven casing</u> or equivalent methods (i.e., no annular materials), it may be possible to pull the outer casing or well *in lieu* of overdrilling. If this procedure is used, grouting must be completed concurrently with the pulling of casing with grout level maintained within 5 feet of ground surface while the casing is pulled. The grout shall be introduced into the well from the base using a tremie line through the innermost casing (with the base of the well removed). The grout mixtures and procedures shall be as described in Step 6.

   <u>Driven casing wells completed entirely in competent bedrock</u> may be decommissioned without removing the casing by tremie grouting according to the procedures described in Step 6.

7. Upon removal of the casing, well screen and annular materials, the resulting boring shall be tremie grouted. The grout shall be a high solids bentonite grout as defined above. Essentially, the grout mixture shall contain as high a bentonite content as can be reasonably pumped (30% bentonite by weight). For wells installed in competent bedrock state regulations often mandate use of a neat cement grout mixture. It is preferable in cases where the borehole intersects both competent bedrock and unconsolidated materials that the unconsolidated interval shall be abandoned using a high solids bentonite grout. Grout shall be mixed to a uniform consistency. The grout shall be pumped into the boring through a tremie pipe placed at the bottom of the boring. The auger flights shall be left in place until the tremie line is situated at the bottom of the boring. Grouting shall proceed in a continuous and expeditious manner by concurrently pulling the auger flights and pumping grout until the grout level is within two feet of the ground surface. Both the bottom of the tremie pipe and the base of the auger flights must remain submerged in grout while the well is grouted.

   After the grout has settled for 24 hours, the borehole must be checked for grout settlement, and if necessary, topped off with the appropriate grout mixture. The final level of the grout shall be within two feet of the ground surface. The top two feet of the borehole shall be abandoned by adding and compacting native soils.

8. Equipment used for well decommissioning shall be cleaned and decontaminated between decommissioning locations.

9. Upon completion of decommissioning activities, well decommissioning materials and equipment will be removed from the site and the site will be restored. Over-drilled well materials and cuttings shall be properly disposed.

10. After the well has been decommissioned, a record must be prepared. The record must contain the following information, at a minimum:
    - Name and address of property owner;
    - Name, license or registration number of the contractor doing the work, name of the driller performing the work, and the signature of the representative;
    - Date work was completed;
    - Survey information including the county, township, range, section, and three quartiles, and the street address or fire number of the well or boring (for unincorporated areas);
    - A description of the geological material penetrated by the well (i.e., copy of the original boring log);
    - The original well or boring depth, and current well or boring depth;
    - The approximate date of construction;
    - The grout or sealing materials, type, quantities, and intervals;
    - The casing type, diameter, and depth, if present;
    - The screen or open hole depth interval, if present;
    - A description of any obstruction, if present;
    - A description of any deviations from the above procedures, or other unusual conditions encountered or actions taken; and
    - A statement as to whether or not all well materials were removed and if not a detailed explanation of the type of materials left in place and their approximate elevation, type, condition, etc.
11. Copies of the decommissioning record are to be forwarded to the site and the State agency if required.

4.1 Failure to remove all well materials

If for any reason the above decommissioning procedures fail to remove all well casing and screen materials, the well shall be permanently marked with a steel post and attached name plate containing the well identification. The name plate and/or site records shall contain, at a minimum, the following:

- Well Identification;
- Date of installation;
- Date of decommissioning;
- Survey coordinates; and
- Approximate elevation interval of in place well materials.

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APPENDIX D

CCR UNIT MONITORING PROGRAM CONSTITUENTS

CCR Unit Monitoring Program Constituents - Analytical Methods
and Limits of Quantitation/Estimated Limits

PARAMETER	CLASS	CAS RN	METHOD	LOQ/PQL (ug/L)	GPS (ug/L)
Alkalinity	inorganic	NA	310.2	15,000	BKG
Antimony	metal	7440-36-0	6010C	20	6
Arsenic	metal	7440-38-2	7010	7	10
Barium	metal	7440-39-3	7010	10	2,000
Beryllium	metal	7440-41-7	6010C	5	4
Boron	metal	7440-42-8	6010C	50	BKG
Cadmium	metal	7440-43-9	6010C	1	5
Calcium	metal	7440-70-2	6010C	5,000	BKG
Chloride	anion	16887-00-6	300.0	5,000	BKG
Chromium	metal	16065-83-1	7010	2	100
Cobalt	metal	7440-48-4	7010	5	BKG
Copper	metal	7440-50-8	6010B	5	1,300
Cyanide	inorganic	57-12-5	9012	10	200
Iron	metal	7439-89-6	6010C	50	BKG
Fluoride	metal	16984-48-8	300.0	300	BKG
Hardness (as CaCO3)	inorganic	NA	SM2340B	2,500	BKG
Lead	metal	7439-92-1	6010C	10	15
Lithium	metal	7439-93-2	200.7	10	BKG
Manganese	metal	7439-96-5	6010C	10	BKG
Mercury	metal	7439-97-6	7470	2	2
Nickel	metal	7440-02-0	6010B	10	BKG
Molybdenum	metal	7439-98-7	6010C	10	BKG
pH	field parameter	NA	SM4500-H	NA	BKG
Radium 226 and 228 combined	radionuclide	(226) - 13982-63-3 (228) - 15262-20-1	903.1 Modified	1.00 pCi/L	5 pCi/L
Selenium	metal	7782-49-2	6010C	50	50
Silver	metal	7440-22-4	6010B	3	BKG
Sodium	metal	7440-23-5	6010C	500	BKG
Sulfate	anion	18785-72-3	300.0	5,000	BKG
Sulfide	metal	18496-25-8	SM-4500	1,000	BKG
Total Dissolved Solids (TDS)	dissolved cations and anions	NA	SM2540C	10,000	BKG
Total Organic Carbon (TOC)	organic	NA	SM5310B	1,000	BKG
Thallium	metal	7440-28-0	6010C	20	2
Tin	metal	7440-31-5	6010B	10	BKG
Vanadium	metal	7440-62-2	6010B	5	BKG
Zinc	metal	7440-66-6	6010B	2	BKG

Notes:

- Class: General type of compound
- CAS RN: Chemical Abstracts Service Registry Number. Where 'Total' is entered, all species that contain the element are included.
- Method: Analytical Method from EPA SW-846 Methods for Evaluating Solid Waste. Samples will be analyzed using the version of each method that is current at the time of sampling. The versions listed in this table (e.g., 6010C) are the current versions as of July 9, 2015.
- LOQ: Limit of Quantitation.
- PQL: Practical Quantitation Limit.
- GPS: Groundwater Protection Standard
- ug/L: micrograms per liter
- BKG: background concentration, as approved by DEQ
- NA: Not Available
- pCi/L: picocuries per liter
- Acceptable alternatives to the analytical methods listed above include current SW-846 Methods with PQLs equal to or lower than the one specified and other laboratory methods as approved by the Virginia Department of Environmental Quality.